Report of the Working group on ARID ZONE RESEARCH

Department of Science & Technology
Government of India
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C O N T E N T S

REPORT OF THE WORKING GROUP ON ARID ZONE RESEARCH

0.0 INTRODUCTION

0.1 Areas having low mean annual rainfall (100 to 450 mm) coupled with high coefficient of variation (40 to 70%), large amplitude of diurnal and annual temperatures, strong wind regimes and nigh potential evaporation characterise the Indian Arid Zone. There are 2.86 lakh sq. kms. of such lands in Rajasthan, Gujarat, Punjab and Haryana States. A substantial portion (about 60%) of our arid zone lies in the Rajasthan that includes the "Thar Desert". From the arid zone standards our arid zone is most thickly populated, the density being 64 persons per km.in case of arid Rajasthan (1981 census) and even higher in the remaining part. What is still more alarming is the fast rate at which the population is growing. Compared to decennial growth rates of 24.7 and 24.9% during the decades 1961-71 and 1971-81 for the country as a whole, the corresponding values for arid Rajasthan have been 28.4 and 36.6% respectively.

0.2 Except in small tracts benefited by irrigation the occupation of the people is basically livestock and a subsitence type agriculture. However, making a living in face of a harsh environment is beset with many a difficulty. Arising out of aridity the surface and ground waters are both scarce and uncertain. Further, these are often of poor quality both for domestic and agricultural uses. Large part of the area is covered by dunes and sandy soils that are highly prone to wind erosion. At other places the soils are shallow or saline. Yield of crops and pastures is open to large fluctuation including complete failure. Periodical adverse conditions lead to a lot of human misery including distress sale of livestock and temporary migration and large scale relief measures by government agencies. The situation is getting worse with the rising human and livestock pressure which in turn is leading to over-exploitation of natural resources and associated environmental degradation.

0.3 The problems of the region and the need for finding a scientific solution to the same have not gone unnoticed from national concern. In the year, 1952, the National Institute of Sciences (presently

the Indian National Science Academy) organised a Symposium on the Rajaputana Dessert which helped in focussing attention on the need for a great deal of knowledge and thought to be followed by careful planning and action programmes. As a sequal to this the Government of India established a Desert Afforestation Research Station, in 1952 at Jaipur, which with the assistance from UNESCO and the Government of Australia developed into a major multidisciplinary set-up, the Central Arid Zone Research Institute. Its foundation was laid on the premise that the arid zone problems were complex and these could best be tackled by a combined effort of several disciplines. The areas of research have been (a) integrated surveys for characterisation and assessment of natural resources namely, soil, landform, climate, surface and groundwater, natural vegetation and landuse; (b) development of technologies consistent with resource potentiality and human needs for afforestation, sand dune stabilisation, pasture improvement, crop production through efficient use of limited water resource, and other improved land-uses; (c) studies on physiological adaptive mechanism and nutritional requirement of desert animals, and conduct ecological studies on wild life and vertebrats pests, particularly rodents, with a view to develop suitable control measures; (d) sociological studies on settled and nomadic population, economics of different farm and livestock enterprises and evaluation of comparative merits of improved practices as an aid to technology transfer. More recently new areas of research like harnessing alternate sources of energy, arid horticulture, exploration of medicinal plants, operational research have been added also. Over the years a wealth of knowledge has been generated. Besides CAZRI, useful contributions have come also from the state and Central Ground Water Boards, G.S.I., B.S.I., Z.S.I., C.S.S.R.I., State Agricultural and animal husbandry departments and the Universities. Based on these a number of development programmes have also been initiated and considerable progress is evident. However, it is felt that a further intensification of research is necessary in a number of key areas to cater to the development and environmental improvement needs.

0.4 Against the above background, the problems of Indian arid zone were discussed at the 5th meeting of the Indo-US Sub-Commission on Science & Technology held in Delhi in February 1980. The concerned Working Group discussed the possibility of collaboration between

institutions of both the countries in specific areas of mutual est and it was suggested that a joint workshop should be organised in India primarily for the purpose of identifying collaborative research programmes. As a follow up of the above recommendation the Department of Science & Technology constituted the present Working Group under the chairmanship of Shri B. Sivaraman, Ex-Member, Planning Commission and Chairman, National Committee on the Development of Backward Areas with a purpose reviewing the present status of R&D in arid zone areas and identifying important sectors in which further intensification of R&D is needed in the country and the area where inputs from USA would be essentially required. The composition of the Working Group and the terms of Reference are as follows : -

1. COMPOSITION OF THE WORKING GROUP ON ARID ZONE RESEARCH

1.	Shri B. Sivaraman, Ex-Member, Planning Commission & Chairman, National Committee on the Development of Backward Areas, Planning Commission, New Delhi.	Chairman
2.	Dr. S.K. Das, Addl. Director-General, India Met. Department, New Delhi-110 003.	Member
3.	Dr. H.S. Mann, Director Central Arid Zone Research Institute, Jodhpur.	Member
4.	Prof. P.D. Bhavsar, Chairman Indian Space Res. Organisation, Ahmedabad.	Member
5.	Dr. G.M. Banerjea, Dy. Director-General Geological Survey of India, Jaipur.	Member
6.	Dr. D.K. Biswas, Director, Deptt. of Environment,	Member
7.	Prof. RV Rama Rao, Head, Geo Engg Divn. Andhra University, Visakhapatnam.	Member

8. Dr. DK Rakshit — Member-Secretary
Principal Scientific Officer,
Department of Science and Technology
New Delhi.

II. TERMS OF REFERENCE

1. To review the status of R&D in Arid Zone problems in the country
2. The identify important sectors in which R&D is needed in the country.
3. To identify institutions/individuals in the country for undertaking the needed research.
4. To encourage co-ordinated R&D for finding solutions to the Arid Zone problems of the country.
5. To identify specific geographic areas, and scientific problems where US inputs will be of benefit to the country.

0.5 Objectives/Strategy

0.5.1. The Working Group at its first meeting held on 29th November 1980 formulated its objectives and strategy to understand the basic problems associated with the arid zone which includes availability of natural resource, their optimum utilization, socio-economic conditions of the people and the present status of our knowledge and dificiency to solve many of our arid zone problems. The Working Group realised that there is a need for intensification of research in applied science of forrestry, agriculture and grassland. To orient resources in relation to Ariz Zone problems there is also a need to conduct detailed surveys of basic resources and carry out research taking into account the inter-relationship between soil-plant-atmosphere, water and energy and also study human-animal relationship. With the above objective in view it was decided to look into the basic research so far carried out in the field particularly by CAZRI, Agricultural Universities of Rajasthan, Haryana and Gujarat, Geological Survey of India, India Meteorological Department, Indian Space Research Organisation. As regards applied research including transfer of results to the field i.e. users in the villages the present status of work undertaken by CAZRI, Central Soil Salinity Research Institute, Karnal would be considered.

0.5.2 While doing the above exercise it was felt necessary to consider the availability of adequate infrastructure facilities in the country for both basic and applied research - need for any augmentation of facilities training of field officers, socio-economic aspect of the area under consideration.

0.5.3 **Accordingly it was also decided that status report on the R&D** work so far done and their impact on arid zone development identifying the gaps where further intensification of research need would be prepared for the purpose of giving suitable recommendations. It was also decided that the aspects related to transfer of technology to the common man's level in the village would be considered separately in consultation with the concerned State Government representatives for making suitable recommendation.

0.5.4 The Working Group held 5 meeting : on 29th November, 1980; 29-30th May, 1981; 25-26th August, 1981; 7-8th September, 1981; and 22-23rd September, 1981. 13-14th Oct., 1981, 29th Oct., 1981 and 13th November, 1981 (Annexure I to IV). At the 4th meeting held at CAZRI, Jodhpur on 7-8th September, 1981, it was decided that the report would contain various chapters entailing all problems of arid zone alongwith recommendations for future R&D work in respective areas.

0.5.5 At the third meeting of the Working Group on 25-26th August, 1981 the problems associated with development of location specific technologies, surface and ground water resources, evaporation sedimentation aspect and utilisation of non-conventional alternate source of energy for desalination of water and other uses etc. were discussed. It was observed that due to longer sunshine and more number of cloud free days solar energy can be fruitfully utilised for various development programmes in the region. The meeting also discussed on a suggestion of holding a joint Indo-US Workshop on Arid Zone Research. Members felt that such a workshop would be useful for exchange of knowledge in this area and identification of any specific collaborative research project of mutual interest.

0.5.6 At the fourth meeting of the Working Group held on 7-8th September, 1981 at CAZRI, Jodhpur the Working Group was apprised of work done by CAZRI so far for the development of Arid Zone. The problems associated with transfer of technology to village level was discussed with the senior officials of the State Governments of

Rajasthan and Gujarat. Though the representative of State Government of Haryana could not participate, their problems were duly taken note of. It was decided that the draft report will contain deliberations of the Working Group in different chapters alongwith recommendations. The draft report was considered by the Working Group at its fifth and sixth meeting held on 22-23rd September, 1981 and 13-14th Oct., 1981. The report was finalised at the 7th and 8th meeting held on 29th Oct., 1981 and 13th November, 1981 respectively.

0.5.7 The status report on various aspects of Arid Zone Research are given in the following chapters. Relevant Recommendations about future research are included in the respective chapters.

CHAPTER I

SETTING OF THE ARID ZONE

1.1 CLIMATE

1.1.1 The mean annual rainfall over the north-western hot arid zone varies from 100 to 450 mm in Rajasthan, 300 to 500 mm in Gujarat and 200 to 450 mm in Haryana. Of the total rainfall, generally 85 to 95% is received during the South-western monsoon months and it is only in case of Haryana and extreme northern Rajasthan that winter rain of some significance is experienced. As against this, the annual potential evapo-transpiration values vary from 1660 to 2063 thereby giving aridity index values of 67 to 89. Besides low quantum, the rainfall is open to high year to year variability-the coefficient of variation being about 40 per cent for Sikar and Jhunjhunu and as high as 70 per cent for Jaisalmer. Other stations values lie between these two limits. Further, there are situations of late onset or early withdrawal as well as of extended drought during the main growing season. Table 1 presents an analysis of droughts for some stations in arid Rajasthan as an illustration.

Table 1 : FREQUENCY ANALYSIS OF DROUGHTS FOR SOME REGIONS FOR THE PERIOD 1956 TO 1975

Crop	Degree of Drought	Number of droughts during the study period in different regions		
		Sikar	Jodhpur	Barmer
Pearl millet	Moderate	1	3	3
	Large	2	2	-
	Severe	1	1	1
	Disastrous	-	1	2
Pulses	Moderate	-	2	1
	Large	3	3	3
	Severe	-	2	1
	Disastrous	1	1	3

1.1.2 Another characteristic feature or the arid zone is its strong wind regime and resultant high incidence of dust storms and sand movement. The winds build-up from April and are the strongest during May,

June and July with Bhuj, Dwaraka, Rajkot, Jaisalmer and Phalodi recording mean wind speeds of 18 to 28 kmph. However, this is only the mean value and wind velocities of 30 to 40 kmph are quite common during part of the day.

1.1.3 Causes of aridity : The atmospheric humidity in arid zone during the monsoon period is as high as that in semi-arid and sub-humid regions. Despite this the precipitation is poor. This may mainly be attributed to the high quantity dust content present in the atmosphere up to about 9 kms above sea level. Dust layers absorb solar radiation causing a thermal in version in upper air which results into subsidence. This checks the growth of cloud masses. Further more dust being non hydroscopic aerosol, it does not allow cloud droplets to grow to the size of rain drops. It is only when monsoon depressions move close to or over this region causing break in the inversion, that wide-spread good rainfall occurs.

1.2 GEOLOGY

1.2.1 The region is characterised by an entire range of formations from the Lower Pre-Cambrian to the quaternary. Amongst the oldest are the Banded Gneissic Complex, the Aravallis, Racalo, the Delhi's and the acidic and basic instrusive and volcanic flows. The sedimentary rocks of the Palaoezoic, Mesozoic and Tertiary rest on these. The Mesozoic and Tertiary formations are sediments deposited in paralic to shallow neritic environment. During early Jurassic period there tool place the deposition of Lathi in Jaisalmer and Barmer basin. This was largely under a fluviatile condition though later facies are mixed or marine. However, major marine transgressions took place in Middle Jurassic, Upper Cretaceous, Late Palaeocene and Upper Eocene periods. The Quaternary was characterised by a massive alluvial activity which to form by far a major part of the arid zone followed by the latest Pleistocene and the Recent sand spread of acolian sands. The Gujarat arid zone has mainly the Jurassic and Cretaceous as the oldest rocks. This together with the Tertiary are either terrestrial or marine. Gypsum, bentonite, fullers earth, salt, limestone, marble and building-stones are some of the important minerals. The Delhi and Pre-Delhi rocks have important occurrences of copper, zinc and lead. Sizeable deposits of lignite and potash have also been reported.

1.3 LAND-FORMS AND SOILS

1.3.1 Pleistocene alluvial plains varyingly covered by younger wind worked sands constitute by far the most extensive feature of the arid region. These plains have an elevation of 350 to 450 m above mean sea level at the foot of the Aravallis in the east and from here these slope in the westerly and south westerly directions to about 100 m in the west and 20 m in the south-west towards the Rann of Kachchh. However, this general slope is broken at a number of places by small and big hills and plateaux and the associated rocky and burried pediments and piedment plains.

1.3.2 Most spectacular among the landforms are the dunes. In arid Rajasthan dunes in varying degree of frequency cover 58% of the area. Dunes occur in two major chains. One of these lies in the western parts of Barmer, Jaisalmer and Bikaner districts and is made up of high dunes, often 20 to 100 m hign and many a kilometers long. The other covers eastern part of Bikaner and Churu districts. Discontinuous dune fields are scattered in the major part of the rest. The dunes comprise six types namely, the obstacle, parabolic and coalesced parabolic, longitudinal, transverse, barchan and shrub coppice. The duny landscape covers a major areas of Haryana and to some extent also of Gujarat, though with a reduced height and frequency of occurrence. The dunes are highly sandy (93 to 96% sand within which 0.12 to 0.18 mm size grains by far predominate) and contain only 1.8 to 4.5% clay and 0.4 to 1.3 silt.

1.3.3 The associated sandy plains have somewhat more of clay and silt and a weakly developed structure. These have generally a slightly to moderately developed lime concretionary strata at 40 to 120 m depth. These together with the dunes cover nearly 65% of the area. In nearly 5% of the area the lime concretionary strata is strongly developed into a hard pan and does not permit a normal growth and stand of shrubs and trees. In major part of Pali and parts of Nagaur, Jodhpur, Jalor, Mehsana and Banaskantha, stretches of brown and grey brown loams are encountered. These soils have a well aggrogated surface and a good water holding capacity. They cover about 15% of arid zone. However, depth of soil is a limitation in some places. A major part of Jamnagar and southern part of Kachchh districts covered with medium black soils. Hills, rocky pediments, the Ranns, inland salt basins, coastal sandy plains constitute the rest.

1.4 CHARACTERISTICS AND PROPERTIES OF SOILS

1.4.1 The dominant soils of the arid zone are light-textured and devoid of any significant structure development. These are prone to severe wind erosion unless properly protected. They have very low water retention capacity. However, these possess high infiltration rate and low hydraulic conductivity in unsaturated state. This permits quick soaking in rain and its conservation against strong atmospheric moisture deficit. The sands also permit easily profiltration of the root system of the plant. However, because of the low water retaining capacity, deep percolation losses are significant. Therefore, optimum use of the profile moisture is possible only through a combination of shallow and deep rooted vegetation. In comparison the medium and fine textured soils have lower water intake rate, greater run-off, greater soil moisture storage capacity and stability against wind erosion. A large number of soil samples from arid zone have been analysed for the inherent fertility status. These show that even the sandy soils are well provided with various nutrient elements, including the trace elements. Humus/nitrogen are low to very low but even their levels are not such as to come in the way of establishment and maintenance of a healthy natural vegetation cover. It is only in case of annual crops that additional inputs are necessary for maximisation of productivity.

1.5 NATURAL VEGETATION

1.5.1 Ecologically, the vegetation of the major part of arid region can be described as belonging to the thron forest type. However, the natural vegetation cover has got greatly transformed due to prolonged and intense biotic influence. As stated elsewhere much of the area of arid zone has come under cultivation and even in the rest the density of natural cover is much less than that permitted by the soil-climate condition. Nevertheless the natural vegetation has a substantial contribution to the productivity from land. Trees like khejri are highly valued and conscientiously maintained. Besides this, a lot of shrubs and grasses are found growing in fallow as well as crop lands and of course in grazing lands. Many a studies have shown that the grasses, shrubs and trees in the area are highly well adapted to the environment.

These are deep rooted, tenacious enough to survive expanded droughts and yet efficient in putting on a good bio-mass during favourable interludes. These are quite palatable and rich in mineral matter. What is more, these occur in great variety - there being as many as 700 species, amongst which grasses along account for 107 species.

1.6 SURFACE AND GROUNDWATER RESOURCES

1.6.1 Arising out of paucity of rainfall, the water resources of the region are scarce. The region, with the exception of some favourable situations, is devoid of an organised drainage system. From the rocky and gravelly surfaces, a number runnels originate, which run for the few kilometer before disappearing. In the dominant sandy tract even these are absent. It is only in the east that a good net work of drainage lines exists. The most prominent amongst them is the Luni System, with a basin area of 34,000 km^2. Kantli, Dohan and Sahibi in the north and Banas are other worth mentioning. Ghaggar River derive most of its flow from the adjoining semi-arid zone. From the central high lands of Kachchh district, a number of stream originate which flow into the Gulf or the Rann. However, flow in the drainage systems not only highly seasonal but also erratic. The runoff has been intercepted at a number of points for building up local water resources.

1.6.2 Investigations over the years by various agencies have made the picture of groundwater availability reasonably clear. Data are available regarding depth of occurrence and quality of water. Exploratory drilling and geophysical surveys have enabled location of new aquifers, namely, the Lathi Basin, Borunda area, Sikar basin and scores of smaller aquifers. As regards arid Rajasthan it has been estimated that of the total annual recharge of 3950 million cubic meter, 2607 mm is already being utilized. Therefore, there is some, scope of expending the exploitation though with a constraint due to depth of pumpage and/or quality of water.

1.7 PRESENT LANDUSE

1.7.1 Amongst arid regions of the world, the Indian arid zone distinguished by its high incidence of arable farming. An analysis of the past data shows that though cultivation has been in vogue for centuries, its rapid growth is a relatively recent phenomenon match-

ing with the spurt in population that started from the early thirties of the present century. Upto the fifties the trend was to bring in more area under utilization, though still in a fallow farming system. Having exhausted most of the cultivatable reserve from them on the emphasis has seen on more regular cropping of the lands under cultivation. The current picture is that in various arid zone districts, with the exception of the most desertic tract namely Jaisalmer and parts of Bikaner, Barmer and Kachchh, 70 to 90% is under plough. Even the dune flanks and such other marginal lands are being cultivated. Besides the common village lands and 'orans' the only lands left out are the salines and very shallow soil or rocky areas. Individual district statistics of land use and the cropping patterns are discussed in another chapter of this report.

1.8 LIVESTOCK

1.8.1 Agriculture in the region is essentially a mixed enterprise with most farming households maintaining a sizeable herd of livestock that is sustained on crop residues and on natural vegetation found growing in fallow and crop land. There are of course families, whose sole resource of livelihood is livestock. Therefore, livestock rearing has a very important contribution to the economy of the region. For example, this sector accounts for 12 per cent of the total income of the Rajasthan State. Nearly 40% of wool produced in the country comes from the arid zone. The cattle from arid zone are reputed for their quality and these find ready market in the neighbouring states.

1.9 LIVESTOCK POPULATION AND GROWTH TRENDS

1.9.1 The population of different livestock species in the arid region of Rajasthan, Gujarat and Haryana are reported in Table 2. These show that as regards Rajasthan, the sheep and goat together constitute 54% of the total livestock, whereas in Gujarat and Haryana these constitute 33% and 15% only. In the last mentioned two states baffaloes also occupy an important position.

Table 2 : LIVESTOCK POPULATION* (000) IN THE ARID DISTRICTS OF RAJASTHAN, GUJARAT AND HARYANA

State	Cattle	Buffaloes	Sheep	Goats	Camels	Total
Rajasthan	4,034	1,380	6,676	6,174	639	18,903
Gujarat	280	135	150	250	11	826
Haryana	514	575	206	150	91	1,576

* 1971-72 Census except of Rajasthan which is for census 1976-77.

An analysis of the livestock population over the years shows that (a) despite the dwindling grazing lands, there is a constant increase in the total numbers and (b) that whereas upto 1966 by and large all type of livestock show an increase, from then onwards the proportion of cattle has started declining and that of goat has increased greatly. So there is a discerning change in composition in the favour of the goat.

1	2	3	4	5	6	7
RABI						
1. Mustard	T-59	5	-	-	Prakash T-59	10
2. Gram	-	-	-	-	H-208 C-235	10
3. Barley	-	-	-	-	RD-56 Jyoti	12
4. **Sanflower**	A-300	4	-	-	EC-35737	10

2.7 CROPPING SYSTEMS

2.7.1 After identifying varieties of dryland crops that are efficient in utilizing rainfall and stored moisture, studies on cropping systems for dryland were initiated at the Central Arid Zone Research Institute, Jodhpur, in 1975. These studies were basically designed to find out the most stable and remunerative system for the arid regions of Rajasthan. Pearl millet, guar beans, mung and costor were grown in single crop systems. The results of six years study are summarised in Table 4.

Table 4 : GRAIN YIELD (q/ha) OF DIFFERENT DRYLAND CROPS UNDER SINGLE CROPPING SYSTEMS

Single Cropping Systems	Yield (q/ha)						
	1975	1976	1977	1978	1979	1980	Mean
1. Bajra-fallow	32.0	18.6	22.9	21.9	2.5	5.2	17.2
2. Guar-fallow	10.6	13.8	14.6	9.8	6.3	5.8	10.2
3. Mung-fallow	7.6	7.0	10.4	9.8	3.9	6.3	7.5
4. Castor-fallow	13.5	9.3	5.2	6.0	1.1	1.0	6.0

NOTE : In 1979 surprisingly low yields of bajra and costor despite it being a high rainfall year (638 mm) are mainly due to late onset of monsoon, flooding condition at seeding stage and early recession of monsoon causing drought conditions at reproductive stage.

Low yields in 1980 are mainly due to long drought spells at active growth and at reproductive stages of crop.

Bajra-fallow system proved to be the most productive (17.2 q/ha) and remunerative. Between Mung-fallow and guar-fallow systems. The latter is promising in terms of productivity (10.5 q/ha). The former system is, however, more paying because of higher price of the produce. Castor-beans-fallow system imparts stability, to crop production on drylands, with good production potential (6 q/ha).

2.8 INTERCROPPING/MIXED CROPPING SYSTEMS

2.8.1 Intercropping, like its Predecessor "crop moisture practised in India from ancient times to meet the domestic needs of the former for cereals, pulses, oil-seeds etc., to minimise the risk of failure of crops and to lessen the incidence of pests and diseases. Particularly in arid regions it is an important farming system to support substance oriented arable farming. Historically, this has been regarded as a primitive practice which would give way to sole cropping as a natural and inevitable consequence of agriculture development. However, it has now been realised that inter-cropping remains an extremely wide spread practice and is likely to stay at least the forseable future This continuing importance of this practice in the farming system is mainly due to yield advantage compared to monoculture, greater stability of yield over different seasons, its role in meeting the weather aberrations. These advantages are especially important from the point of view of the poor farmers because they are achieved not by the use of costly inputs but by simple expedient of growing crops together. A major reason of such yield advantages through intercropping is the more efficient use of growth environments.

2.8.2 Results of some of the intercropping/mixed cropping studies carried out at CAZRI, Jodhpur are given as under :

2.8.2.1 In a trial on system of planting mung beans with and without an intercrop of pearl millet carried out for two consecutive years (1975 and 1976) revealed that the yield of the base crop (mung beans) decreased markedly as a result of planting one row of bajra under any of the planning system. However, the total productivity bajra was the highest in paired rows planting of mung bean + one row of bajra. Further, it is interesting to note that the yield of base crop was reduced by 3.6 q/ha and as against this loss, planting of one row of bajra in interspaces resulted in an additional grain yield of about 22 q/ha of bajra. From the point of view of total productivity and gross returns intercropping system of mung beans + one row of bajra appears to be paying proposition.

2.8.2.2 Studies on intercropping in guar indicated that growing of one row of bajra in the interspaces of guar sown in paired rows and fertilising bajra with 15 kg. N/ha, resulted in the highest productivity (10.3 q/ha) as against 6 q/ha in pure cropping of gaur.

C H A P T E R - II

2.0 AGRONOMIC RESEARCH

2.1 AGRO-METEOROLOGICAL SITUATION IN RELATION TO RAINFALL.

2.1.1 Rainfall Pattern : An analysis of the isohyet map of the arid regions of north-western India indicates that the mean annual rainfall varies from 100 mm in the north-western sector of the Jaisalmer district to 450 mm in the eastern boundary of the arid zone in Rajasthan. It varies from less than 300 mm to 500 mm in the arid zone of Gujarat and from 200 to 450 mm in the Haryana-Punjab region. The general decreasing gradient is from the south-east to the north-west.

2.1.1.1 The analysis of frequency distribution of rainfall data revealed that once in 10 years the annual rainfall of the entire arid zone of north-western India can be less than 200 mm, except for Jhunjhunu, Hissar, Sikar and Pali. Considering 20% probability, the deficit pattern expected once in 5 years, the annual rainfall is less than 200 mm for Jaisalmer, Barmer, Bikaner, Ganganagar, Jodhpur and Nagaur. For Jaisalmer this value is even less than 100 mm. The median values represented by 50 per cent frequency values are invariably less than the mean values.

2.1.1.2 Years of surplus rainfall occur once in a while in Jaisalmer, Barmer, Jalore, Bikaner and Jodhpur districts while deficit rainfall or drought years are more frequent in Barmer and Jaisalmer districts.

2.1.1.3 As regards the seasonal distribution, the main rainy season is from June to September. In Gujarat as well as in southern and central Rajasthan, the contribution of rainfall during the period June to September to the annual rainfall varies from 90 to 95 per cent. In view of the winter rainfall contributing from 9 to 12 per cent to the total annual precipitation, the monsoonal contribution is of the order of 78 per cent in the Punjab and 80 to 85 per cent in Haryana and northern Rajasthan.

2.1.2 A case study of Jodhpur rainfall data.

2.1.2.1 Periodicity and distribution of rainfall : An analysis of the daily rainfall data of Jodhpur for 75 years (1901 to 1975)

revealed that Jodhpur falls in a region of low annual rainfall (366 mm) with 21 rainy days and 80% rainfall received during kharif season (July to September). The normal dates of onset and withdrawal of monsoon are 1st July and 15th September, respectively, restricting the period of moisture availability during the cropping season to 77 days. Mean weekly rainfall and the probability of rainfall occurrence increases sharply from the last week of June (64%) and with the normal monsoonal activity during July, the highest probability (75-78%) is observed during the 29-31 standard week (16 July to 5 August). However, the highest quantum of normal weekly rainfall (about 35 mm/week) are recorded during the last two weeks of August with probability of occurrence ranging from 62-69 per cent. There is a sharp decreasing trend in the weekly rainfall amount as the probability of rainfall occurrence falls below 50% after the first week of September. Interestingly, in few of the years there had been substantial rains (about 100 mm) from the last week of June and extends upto the second week of September.

2.2 PRESENT LAND-USE AND INCIDENCE OF CULTIVATION

2.2.1 Amongst the regions of comparable aridity the world over, the Indian arid zone distinguishes by its high incidence of arable farming. Contributory factors for this are (A) concentration of rainfall in a well defined period, (B) a set of agro-climatically well adapted crops and (C) greater capacity of farming system to satisfy diverse human needs. Though agriculture is being practised for centuries in the region, it seems to have existed as a profession secondary to animal husbandry. It is only during the current century, more specifically from the fourth decade that a process of phenomenal increase in cultivated area has come into being. As a result by the year 1961-62, 70 to 89% of the total geographical area has been brought under cultivation in all the arid Rajasthan districts with the exception of most arid tracts namely Jaisalmer and Bikaner districts and parts of Barmer. This process encompassed lands which has normal agricultural potential as also lands of marginal nature - soil or climate wise. These marginal lands included dune flanks, shallow soils, lands with some salinity hazard. During this period, the pattern on these cultivated lands was largely one of fallow-farming system. To meet the growing human needs, the trend since has been on increase in the regularity of cropping. Whereas in the early sixties on average 50 to 70% of the cultivated area

(ii) Development of solar cookers for performing operations like baking chapatis, frying and cooking meat.

(iii) Development of solar stills of larger capacities to meet community requirement.

(iv) Development of large scale agricultural dryers.

(v) To develop agricultural implements like sprayers, dustors etc. which can be operated by using solar energy.

(vi) To develop solar concentrators with tracking arrangement for producing steam and operation of turbines to lift water and generate electricity.

(vii) To develop suitable cold storage systems using solar energy and natural cooling methods.

11.6 WIND POWER POTENTIAL IN THE ARID REGIONS

The mean wind speeds in kmph in arid region during different months are given in Table 1. The number of days during which wind power can be harnessed for lifting water when the wind speed exceeds 8 kmph at Jodhpur, Jaisalmer and Bikaner are given in Table 2. Generation of electricity utilising wind power is possible when the wind speeds exceed 15 to 16 kmph. Energy saved by a windmill, having a sweep area of 23.6 m^2 for pumping water has been calculated and reported in Table 3.

Table 3 : Estimated energy saved in KWh by one standard windmill (WP-2) having 23.6 m^2 sweep area

Months	Average wind speed in kmph	Energy saved/day/windmill for sweep area 23.6m^2
January	8.9	3.19
February	8.8	3.09
March	9.8	4.27
April	10.0	4.81
May	15.0	15.29
June	18.5	28.70
July	16.6	20.70
August	12.9	9.72
September	10.6	5.40
October	6.6	1.30
November	5.8	0.87
December	7.3	1.77

11.7 BIOGAS TECHNOLOGY

11.7.1 In view of large cattle population in the arid region, work on

2.8.2.3 Intercropping of bajra with moth : Different intercropping systems tried with moth during 1979 and 1980 revealed that among pure cropping systems, moth in paired rows gave the maximum yield. Among the intercropping systems, planting one row of bajra in between the paired rows of moth gave the highest total productivity.

2.8.2.4 Planting systems : Of late, some interest has generated among dryland research workers in trying out the efficiency of newer systems of planting like the paired row system against the conventional (uniform) planting system. The experience gained at Jodhpur and with various crops has shown that the paired row system of planting is not inferior to the conventional system (Table 5).

Table 5 : EFFECT OF SYSTEMS OF PLANTING ON THE YIELD OF DRYLAND CROPS

Planting Systems	Grain yield of bajra (q/ha)		Grain yield of Mung (q/ha)	
	1975	1976	1975	1976
1. Uniform rows	38.1 (45 cm)	22.0	12.0 (30 cm)	7.4
2. Paired rows of bajra	40.3 (30/60 cm)	25.3	12.2 (20/40 cm)	8.1
3. CD (0.05)	MS	NS	NS	NS

2.9 JUDICIOUS FERTILISER USE

2.9.1 Fertiliser use on drylands has almost been non-existent, mainly owing to uncertain rainfall and the cultivation of non-responsive crop varieties. As such, the earlier belief of the dryland farmers that fertilizer application was injurious to dryland crops was justified. With the availability of fertilizer response varieties of dryland crops and the knowledge gained on the quantity, time and method of nutrient application; a judicious fertilizer use can offer enormous possibilities of increasing dryland crop production under normal and above normal rainfall situations and stabilizing them in years of subnormal rainfall.

2.9.2 A. Bajara : Based on the mean of two years (1971 and 1972) it was observed that bajra HB 3 did not respond to the application of nitrogen beyond 40 kg/ha. Results of a long term study are given in Table 6. A long term experiment on fertility management of bajra-bajra and

development of biogas plants is in progress at CAZRI, Jodhpur with the following objectives :

1. to identify non-corresive materials/treatments for use in gas holders
2. to develop biogas plants using stone slabs and other locally available materials.
3. to improve gas output during winter season using solar energy.
4. to study the influence of salinity in water on gas output.
5. to identify suitable microbial stains for improving gas output.

11.7.2 IARI and KVIC type biogas plants were tested under arid conditions and found that metallic gas holder gets corroded within few months. It was perhaps due to the higher salinity contents in the water. To remove this corrosion problem, metallic gas, metallic gas holder was replaced by RCC but this resulted in heavy leakage of gas. This plant being modified by using different plastic sheets to stop gas leakage.

11.7.3 CAZRI should intensify research work on developing domestic and community size biogas plants by involving a team of microbiologist, physicist and a chemical engineer.

11.8 WIND POWER UTILIZATION

11.8.1 A simple sailwing wind mill has been designed, developed and tested at CAZRI, Jodhpur. The design of the wind mill is so simple that its fabrication and maintenance can be undertaken by a village technician. The mill is capable of pumping water for irrigation from shallow depths at an average rate of 670, 1143 and 1512 litres per hour on days with a mean daily wind speed of 9, 15 and 20 kmph respectively. The cost of fabrication of windmill works out to approximately Rs.3000 per unit.

11.8.2 A vertical axis type wind mill has been designed and developed and the installation work is in progress.

11.8.3 Work on development of a small aerogenerator cum battery charger is also in progress.

that would enable the crop to over come the long spells of drought at critical growth and developmental stages, should be incorporated alongwith the other factors conducive to a high harvest index and consistent yielding ability. In order to offer better insurance against crop failure, it is necessary to develop plant types for mixed crops, taking into consideration various components of competitive ability and complementary.

2.6.2 Presently, most of the Dry Farming Research Centres are mainly concerned with evaluation of the existing and newly developed crop varieties available from various crop improvement programmes. This is being done with a view to identify efficient varieties for certain specific situations. Information on efficient crops and their varieties for arid region is now available (Table 3).

Table 3 : CROPS AND THEIR IMPROVED VARIETIES SUITABLE FOR ARID REGION OF RAJASTHAN, GUJARAT AND HARYANA

Crop	Rajasthan		Gujarat		Haryana	
	Varieties	Yield potential (q/ha)	Varieties	Yield potential (q/ha)	Varieties	Yield potential (q/ha)
KHARIF						
1. Bajra	BJ104	17	BJ104 CJ104	20	BJ104	20
2. Jowar	CSH-1 CSH-5	18	CSH-5 CSH-6	20	-	-
3. Guar	D.S. 2470(12), FS 277	10	Malosan Kutch-8	10	D.S. No.2 HFG-75	10
4. Urid	-	-	-	-	Salooni T-9	10
5. Mung	S-8, S-9 PS-16	8	Gujarat-1	7	S-9,S-8 Jawahar-45	9
6. Moth	T-18 T-2 Jadia	7	-	-	T-2 T-9	10
7. Cowpea	FS-68 C-20 K-11	8	Charodi-1	8	C-152 S-5269 FS-68	8
8. Sesame	T-13 TC-25	6	MURG-1 Gujarat-1	7	-	-
9. Castor	Aruna R-63 Gauch-1	6	GAUCH-1 GAU-1	12	Aruna R-63	8

11.8.4 There is no other Institute in the arid region working on wind power utilization. However, many other Institutes in the country are working on wind power utilization and developed different windmills for pumping water as well as for generation of electricity. Prominent among them are :

1. Bharat Heavy Electricals Limited, Hyderabad.
2. TOOL-ORP Windmill Project, Ghazipur, UP.
3. Indian Institute of Science, Bangalore.
4 Shri A.M.M. Murugappa Chettiar Research Centre, Madras.
5. National Aeronautical Laboratory, Bangalore.

11.9 RECOMMENDATIONS

There should be exchange of prototypes developed at different institutes for locating area specific problems.

Table 1 : Mean wind speed in kmph at various stations in arid zone of India*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean
						PUNJAB STATE							
Ferozepur	1.8	2.6	3.3	3.3	3.5	3.2	2.8	2.2	2.0	2.5	1.4	1.3	2.4
						HARYANA STATE							
Hissar	5.5	6.4	7.3	7.4	8.5	10.1	9.6	7.9	6.9	5.3	4.5	4.9	7.0
						RAJASTHAN STATE							
Ganganagar	4.0	5.0	6.4	6.8	8.0	10.7	13.3	8.0	6.2	4.7	3.3	3.4	6.7
Bikaner	4.6	5.1	6.5	7.3	10.1	13.3	12.8	11.0	9.4	5.3	3.5	3.7	7.7
Sikar	6.1	6.2	7.9	8.0	9.4	11.6	9.2	7.8	7.3	5.1	4.3	4.9	7.3
Phalodi	10.0	8.8	12.9	14.1	20.7	25.6	23.6	19.4	16.6	11.6	11.8	8.3	15.3
Jodhpur	8.9	8.8	9.8	10.2	15.0	18.5	16.6	12.9	10.6	6.6	5.8	7.3	10.9
Jaisalmer	8.6	8.2	10.9	12.7	18.3	27.2	24.8	21.7	16.1	8.5	5.5	6.5	14.1
Barmer	7.6	7.5	9.1	10.6	12.9	14.2	12.4	10.6	9.6	7.2	5.3	6.4	9.5
						GUJARAT STATE							
Bjuj	7.9	8.1	8.5	11.2	17.6	21.0	20.0	17.0	13.0	8.6	7.0	5.9	12.1
Dwarka	13.5	14.8	16.1	16.7	20.0	23.5	27.1	21.9	15.0	11.8	12.4	12.3	17.1
Jamnagar	8.8	7.8	8.8	11.1	15.9	16.2	15.6	14.2	9.7	7.0	6.9	7.5	10.8
Rajkot	13.1	13.6	16.6	19.7	26.2	28.1	28.3	23.2	17.4	12.1	10.6	11.3	18.3

* Source : India Meteorological Department (1966) Climatological Tables of Observatories in India 1931-60.

Table 2 : Average number of days with mean daily wind speed more than 8 kmph at some stations in western Rajasthan*

	Average number of days with mean daily wind speed of more than 8 kmph											
	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Jodhpur	13	13	18	20	28	29	28	27	20	9	6	10
Jaisalmer	19	16	23	23	28	30	30	30	27	14	7	11
Barmer	1	2	6	10	20	26	25	22	17	5	-	1
Bikaner	1.1	2.5	5.8	9.7	19.6	26.1	25.5	22.3	17.1	5.0	0.3	0.75

* Source : Krishnan, A. and Garg, H.P. (1975) Wind Power for pumping water. Indian & Eastern Engineer. pp 105-109

CHAPTER XII

12.0 SAND DUNES AND SAND MOVEMENT

12.1 INTRODUCTION

12.1.1 Arid as well as semi-arid areas - north west of the Aravallis, are covered by aeolian or alluvial sand deposits. The wind erosion and shifting sands are posing main problems and the conditions within the desert are deteriorating. In a situation like this, steps to control drifting of sand are needed as a prerequisite before any developmental scheme is undertaken. In the Indian desert there are wide expanse of wind blown sand. In the arid zone the dunes are not only a menace to the farmers and soil erosion but also the roads, railways permanent structures, etc.

12.2 EXTENT AND DEGREE OF SAND DUNES IN NORTH WEST ARID ZONE OF INDIA

12.2.1 Map 1 shows the extent and degree of sand dunes in the NW Arid Zone of India. The map has been prepared on the basis of the informations given in Survey of India/1:253, 440/topographical sheets; available maps, literatures, aerial photographs and landsat imageries. The purpose of the map is to visualise the extent of the sand dunes, towards the east of the desert as well as the regional variation of the intensity of dunes in the various parts of the Indian desert. The map indicates that the occurrence of the dunes towards the east of 500 mm isohyet is extremely limited. Along the margin of 500 mm isohyet, the distribution of sand dunes and their concentration is very low - below 20% of the area. The extent and distribution of dunes in different states as worked out from Map 1 are presented in table 1. In Indian Arid Zone out of the total approximate area of 2,95,00,000 ha, 1,70,02,672 ha or 57.85% area are affected by sand dunes. Statewise variations indicate that the 69.14; 65.68 and 19.41 per cent respectively of the arid zone of Rajasthan, Punjab and Haryana and Gujarat states are respectively affected by the sand dunes of various intensities. Considering the western Rajasthan alone (west of the Aravallis) the 58.5 per cent of the total area (2,13,68,853 ha) has been affected by the sand dunes. The dune fed areas of Rajasthan; Punjab and Haryana and Gujarat includes respectively 43.37, 10.56 and 4.25 per cent of the total dune fed area (1,70,02,672 ha) of the N.W. Arid Zone of India. The worst affected

districts are Barmer and Jaisalmer. The area under Polayat, Nokha and Chattargarh in Bikaner district comes next in severity. In general menace of sand dune decreases towards east and north in Indian Arid Zone.

12.2.2 In the eastern Rajasthan dunes are mapped in two localities, where the total area affected never exceeds more than 20 per cent. The dunes cover only 34,816 ha or 0.2 per cent of the total area of eastern Rajasthan.

12.3 DUNE MORPHOLOGY IN RELATION TO SOILS AND VEGETATION

12.3.1 Six types of sand dunes viz. obstacle, parabolic and coalesced parabolic, longitudinal, transverse, barchan and shrub coppice, have been recognised in Arid Zone of India. These dunes originated under past arid phases and were established during intervening humid phases.

12.3.2 In obstacle dunes the soil is well developed Lobtadenia pyrotechnica-Acacia jacquemontii, Lycium barbarum community dominates on these dunes. The height of these dunes vary from 30 to 45 m.

12.3.3 The parabolic dunes are also stabilised and vegetated. The slopes of the leeward sides of these dunes are steep and of windward sides are gentle. The soils are sandy and calcareous. The dominant plant community is Calligonum polygonoides, followed by Acacia senegal. The ground layer has high plant density (2053 plants/ha) of Panicum turgidum. The height varies from 30 to 138 m.

12.3.4 The longitudinal dunes, are also mostly stabilished. The soil characteristics of these dunes are almost similar to the parabolic dunes except E.C. which varies from 94-423 mmhos/cm respectively. Calligonum polygonoides and Lycium bargarum from the dominant community of dunes. The height of the dunes ranges from 15 - 16 m. The soils of transverse dunes are highly calcareous and compact. The moisture, PH and other characteristics of the soils and vegetational characteristics are similar to the longitudinal dunes. The height of the above two dunes varies from 12 m to 15 m or even more.

12.3.5 In the barchan dunes the soils are loose and non-calcareous. There is no vegetation on these dunes except Cyperus arenarius, Aerva

persica and Citrullus, colocynthis on their extended arms. The altitude of the dunes ranges from 3 to 5 m. Shrub coppice dunes are formed against shrubs, bushes and fences and do not have any definite shape. Like the barchans these dunes are also active and have 1 to 3 m heights. Slope is highly irregular. These are common in interdunal plains. The spoils are loose and permeability is rapid. The vegetation type is similar to that of barchens.

The above classification has been made mainly on the basis of field observations in the surveyed areas of Rajasthan, Haryana and Gujarat. This has been aided by remote sensing studies in Indian desert as a whole.

12.4 LANDUSE OF THE SAND DUNES

12.4.1 In actual practice, sand dunes are not universally sandy wastes. These are rather often cultivated during rainy season. The active sand dunes are also often wastelands but the lower and middle flanks of these dunes are cultivated in years of very good rainfall, particularly in rainfall zone of over 200 mm. Long fallows of five years duration in 200 mm - 300 mm rainfall zone and 2-3 years duration in rainfall zone of over 300 mm are evident. Upper flank and crests of the dunes serve as grazing ground of the livestock. Hence, in sand dunes, three land use units viz. cultivated or cultivable (including short and long fallows) sandy waste and grazing ground can be mapped. But these details can be mapped only on 1:50,000 scale or above. Such minute details cannot also be readily identified by traditional ground survey. This, however, is possible by aerial photo interpretation particularly "edge gradient" study

12.4.2 The findings of aerial photo interpretation and consequent ground survey regarding land use are as follows :

Table 2 : Landuse of the sand dunes

Dune particular	Landuse	Remarks
Stabilised dunes and sandy plain: lower and middle flank	Cultivated	Soil erosion is menace to adjacent land
Stabilised dunes: lower and middle flank	Short fallow	

Stabilised dunes: middle and upper flank	Long fallow	Cultivation should not be practised which may lead to the encroachment of of sand in adjacent fertile lands.
Unstabilised dunes and marginal lands: crests	Sandy waste	Recommended for range land
Unstabilised sand dunes: crests and upper flanks of stabilised sand dunes	Grazingland	Controlled grazing is recommended.

12.4.3 Uneconomic landuse, overgrazing and indiscriminate cutting of trees and have resulted in increase of desert sand and formation of huge mobile or active sand dunes in many areas e.g. phalsand-Pokran tract in Jaisalmer district (Banayana area).

12.5 SOURCE AND ORIGIN OF DUNE SANDS

12.5.1 The findings of the various agencies can be summed up as follows :

(a) The source of the sand is mostly the past dry river beds which aggraded during the arid phases.

(b) Some amount of sands were transported from the western coast as revealed by the presence of foraminifera in the sand dunes as well as of the sand grain surface features (studied under scanning electro-microscope).

(c) Part of the sands are also derived directly by the aeolian agencies due to wind erosion on the existing land farm.

(d) Part of the sands are also derived from the reactivated sand dunes due to uneconomic landuse practices on them.

12.5.2 The problem is however of primary importance and further studies are needed.

12.6 MOVEMENT AND ENCROACHMENT OF WIND BLOWN SANDS

12.6.1 On the basis of recent comparative studies of old maps of the Survey of India, aerial photo mosaics of some areas and from same field

observations, a map of Rajasthan and another of the desert region of N.W. India have been cartographed showing the increase and decrease of desert sands (Map 2). The maps show that there has been an increase of desert sands within the desert in the recent years. In a similar study Survey of India concluded that some spreading of the desert to the N.E. has taken place in Punjab. Haryana and N.E. Rajasthan (Survey of India sheet chart A 1945). Beyond the desert towards the east, increase of sands to some extent is evident in the following localities :

i) Northern Alwar and northern Jaipur districts.

ii) Along the Banas river in Sawai Modhopur, Tonk and Bhilware districts.

12.6.2 It is possible that the problem is much more extensive. Accordingly there is a need for further investigation.

12.6.3 The Aravallis, physiographically, is considered as the eastern limit of the Indian desert. In general, it is high enough to prevent the penetration of wind blown sands towards the further east. But there are several, at least four breaks along the Aravallis, which may allow some accumulation of wind blown sands towards the east because their locations are along the direction of the prevailing wind. These are (i) the Kantali-Sota Sabe break; (ii) The Sambhar gap; (iii) the Luni gap; (iv) The Jawai gap or the Sirohi saddle. Visualising the problems further studies along the gaps and their environs are necessary.

12.6.4 Recent investigations have shown a slow advance of sandy materials through the Luni and Sambhar gaps engulfing more fertile lands towards the coast of the Aravallis causing disorganisation of the drainage system like the Mendha, Kantli, etc. Whether this phenomena is a feature outside the present climatic boundary of the Arid Zone necessitates investigation.

12.6.5 The study reveals :

(i) Fresh sand movement is an active phenomena in the Arid Zone.

(ii) The general trend of the increase of sand is towards the NW of western Rajasthan, Punjab and Haryana and to some extent in the Jaipur district and its environ in eastern of Rajasthan.

used to be cropped, in the mid seventies the figures has risen to 65 to 90%. Similar is the picture for arid zones of Haryana and Punjab. In Jamnagar and Kachchh districts of Gujarat the cultivated area is only around 50% and 15%, respectively as the rest is unfit soil wise for farming. Data in respect of present landuse for different districts in arid Rajasthan is given in Table 1 (in para No. 5).

2.3 PRESENT STATE OF AGRICULTURE

2.3.1 Use of agro-climatically well adapted crop species, mixed cropping or scheduling of crops to cope up with erraticity or delayed onset of monsoon rains, conscious effort at maintaining useful top-feed species as an insurance for survival are the hall mark of arid agriculture as it is practised in the region. Further, agriculture here is also essentially a mixed farming enterprise wherein most farming households keep a sizeable herd of livestock that is sustained on crop residues and natural vegetation that grown in crop as well as fallow lands. However, despite its evolved nature, productivity from land is low, Prime reasons for this are : the removal of natural vegetation as a result of uncontrolled grazing, the felling in trees and shrubs for fuel leading to a large scale soil and nutrient loss due to wind erosion; lack of moisture and restricted period of moisture availability; lack of appropriate soil and water conservation measures; restricted choice of crops and varieties fitting into existing rainfall pattern, competition from extraneous vegetation and non-use of modern inputs like improved varieties, fertilizers, pesticides etc.

2.4 EXISTING CROPS AND CROPPING PATTERNS

2.4.1 The matter has been a subject of study for a long time in the country but the most exhaustive treatment is that from the National Commission on Agriculture (1974). Using total rainfall and its distribution, the commission had divided the arid zone into four regions and within each of these regions an analysis of cropping pattern has been made using the tehsil as the unit of study. Results show that in the major agricultural region i.e. C_2, D_1, E_1 (i.e. the region having less than 5 cm rain in June, 10 to 20 cm each in July and August and 5 to 10 cm in September) bajra occupies 50 to 70% of the cropped area in 20 out of 51 tehsils. Pulses, Jowar and fodder each occupy 10 to 30% land. In five tehsils, bajra occupies even

(iii) Cultivation on the dunes and marginal lands are causing the sands to shift and deteriorating the adjacent fertile lands. Because of decrease of sands in an area is closely followed by an increase in the nearby lands. Fresh deposition is going on in the desert and the desertic conditions are further deteriorating are well evident. This is leading to more intensive desertification and mobile sand left formations around more arid/semi arid urban pockets.

(iv) The reactivisation of stable dunes, due to biotic interference, viz. uneconomic landuse, overgrazing, urban fringe activities etc. is leading to loosing of the sandy materials and causing wind erosion and sand movement more active. The process is more intensive in the vicinity of abadi (settlement) lands : highways, canals, railways, roadways, etc.

(v) Photo interpretation has shown the increase of sand deposits along the Aravallis immediately towards the west of the Sambhar gap due to constant cultivation of the sand dunes in Nagaur district. The interpretation of landsat imageries and field study has shown the reduction of the Mendah river, even towards the east of the Aravallis. GSI was the first to indicate the area and a joint investigation by the CAZRI and GSI was then made. Towards the NE of Jaipur, the width of the Mendah has been considerably reduced. There are at least three sites along its tributaries where there are evidences of the shrinkage of the river bed in the sands. Whether or not these are due to alluvial suffocation require further investigation. It is also necessary to investigate if the sands are of fluviatile or aeolien in origin.

12.6.6 The results obtained above imply that it should be possible to carry out reliable change detection studies through multi-temporal analysis of Landsat data regarding the critical, physical and biological indicators of desertification. The interpretation of computer based may, however, provide slightly higher mapping accuracy though very expensive. CAZRI and GSI should be provided with necessary equipments for such mapping.

12.7 FUTURE RESEARCH NEEDS AND PLAN OF WORK

12.7.1 The foregoing paragraphs in brief outlined the research conducted on the genesis and movement of sand dunes mainly in Rajasthan desert. On the basis of the work research papers and a few monographs and technical bulletins have also been published for dissemination of the technical knowledge. However, looking to this most important problems which is of primary importance to study the extension and deterioration of desert, the investigations on the following aspects need to be intensified. These along with the agencies proposed to undertake the research are given below.

12.7.2 Further investigations are needed on the movement of desert sands particularly in the marginal area to (i) assess vulnerability to desertification, (ii) predict onset of desertification before it starts, (iii) monitor progress in areas suffering from desertification and considered to be at risk and (iv) assess the effect of desertification processes and of programmes to combat them.

12.7.3 The work plan prepared is given below :

(i) Observations to be recorded :

Features	Direct Monitoring	Indirect Monitoring
Moving of Dunes (Direction and speed)		
in the field on aerial or satellite imagery	Movement in m/year location of dunes at intervals of 10 or 15 years	
Deflation of fine material		
in the field	increase in coarse material in surface	Frequency of
on aerial or satellite imagery	darkening of stoney zones	
Sandy cover and beginning of sand accumulation		
in the field	nobkha formation; increases of sand at surface	increase of cultivated area
on aerial or satellite imagery	increase in reflection shadow and/or relief	
Enlargement of rock outcrops or indurated horizon on the surface cause by erosion		
in the field	decreasing or disappearance of annual vegetation	increasing of run-off, alkalinisation; loss of organic matter
on aerial or satellite imagery	enlargement of spots associated with bare areas	

(ii) The area to be looked after by the different agencies are -

1. Sand activity and movement

a) The entire Great Indian Deserts - by Central Arid Zone Research Institute and State Universities and State Agricultural departments.

b) Marginal areas of the desert and semi-desert areas :

i) Rajasthan - Central Arid Zone Research Institute and Geological Survey of India; State Forest Department.

ii) Marginal area of Haryana - Central Arid Zone Research Institute and Agricultural Universities of Haryana and Punjab and State Forest Departments.

iii) Marginal areas of the desert in Gujarat - Geological Survey of India and Central Arid Zone Research Institute of India

2. In order to find out the nature of the sands : if it of fluviatile or aeolian origin, it is necessary to carry out detailed minerological and petrological analysis of the sand grains of the different areas. It is proposed that GSI should look after this programme of work.

3. Source of desert sand - Central Arid Zone Research Institute, Geological Survey of India.

4. It has been observed that the movement of sand and formation of new sand dunes are mainly due to the result of uneconomic landuse practices. Hence it is necessary to carry out a detailed landuse survey of the dune infested areas particularly in the marginal areas of the desert. This can be carried out through multi-temporal analysis of Landsat data, interpretation of aerial photographs with 20 per cent of ground truth investigations. It is proposed that this work should be carried out in Rajasthan by CAZRI, in E. Rajasthan by the CAZRI and GSI, and in Gujarat and Haryana by the CAZRI, Universities in collaboration with National Remote Sensing Agency, Hyderabad and Indian Space Research Organisation, Ahmedabad and Agricultural Department of the respective state Governments.

(iii) Priority areas : Priority should be given to the following areas (Action : CAZRI and GSI) :

1. Wind gaps or breaks along the Aravallis and their environs.
2. The Churu district of Western Rajasthan.
3. The Ghaggar bed (Rajasthan and Haryana).
4. Environs of Lunkaransar, Mahajan, Surgatgarh (Rajasthan; Elhanabad, Sirsa, Bhattu Kalan (Haryana), Bhatinda and Ferozpur (Punjab) and Bhuj (Gujarat).

(iv) In view of the above the following recommendations are also suggested (CAZRI & GSI) :

1. Stable and unstable dunes should be geomorphologically determined and mapped. Stable dunes with naturally regenerated vegetation should not be interfered with. It should simply be protected from grazing and lopping.

2. Sites for new plantations should be determined by geomorphic considerations. The courses of the buried streams for example, are suitable to support plantations. Many more spots may be identified and mapped where there is good storage of subsurface water.

Table 2 : Degree and extent of sand dunes in N.W. Arid Zone of India (Great Indian Desert)

Degree of sand dune based on percentage of area covered by sand dunes	State	Rajasthan	Punjab & Haryana	Gujarat	Total area in ha	% of the total area of NW arid Zone of India
	Total area under arid zone in ha	1,81,06,200	47,43,700	66,50,100	2,95,00,000	-
1	2	3	4	5	6	7
Slight 0 to 20%	(a)	18,90,285	18,56,500	8,28,800	45,75,585	15.51
	(b)	21.7%	39.14%	12.56%	-	
Moderate 20 to 40% of the total area affected	(a)	39,78,225	1,44,000	4,55,800	45,78,025	15.51
	(b)	21.97%	3.04%	6.85%		
Strong 40 to 60% of the total area affected	(a)	34,32,211	11,14,700	-	45,46,911	15.41
	(b)	18.96%	23.50%	-	-	
Severe 60 to 80% of the total area affected	(a)	10,16,491	-	-	10,16,491	-
	(b)	5.61	-	-	-	3.00
Very severe 80 to 100% of the area affected	(a)	24,85,660	-	-	24,85,660	8.42
	(b)	13.73%	-	-		
Total and % to total area of arid zone in state (within bracket) and total area of arid zone of N.W. India		1,28,02,872 (69.14) 43.39	31,15,200 (65.68) 10.56	12,84,600 (19.41) 4.25	1,70,02,672 (57.85)	57.05

(Total area of N.W. Arid Zone, 2,95,00,000 ha)

(a) Area in ha

(b) % to total arid zone of the state

CHAPTER XIII

13.0 ENVIRONMENTAL MONITORING

13.1 INTRODUCTION

13.1.1 The primary base for economic development of arid and semi-arid regions like other regions lies in their natural resources. By natural resources we include whatever man finds of value in his physical environment : soil, water, vegetation, minerals, energy sources and terrain. The process of economic development consists largely of organising the development and productive exploitation of natural resources in the interest of the whole community. To do so effectively it is imperative to know what resources it has and where they are in quantity and location in order to harness them effectively. In pursuance of this objective, a scientific assessment of natural resources (climate, land, water, **vegetation, livestock,** human population etc.) has been made through multidisciplinary integrated surveys at CAZRI and specific detailed studies. As a result knowledge has become available for 93,500 km^2 area as follows :

State	Area covered (km^2)			% of the arid zone covered
	Reconnaissance	Semi detailed	Total	
Rajasthan	32,303	54,379	86,682	44.2
Gujarat	-	1,356	1,356	2.2
Haryana & Punjab	3,516	-	3,516	12.9
Karnataka	2,067	-	2,067	25.7

13.1.2 To enhance the utility of this information in development planning, the land attribute date generated by the above survey are integrated to form major land resource units and each such unit is described for its present landuse, management and productivity, scope for improvement and suggested treatments for realising the same.

13.1.3 In view of the importance of these resource data for rational area development planning, the CAZRI is extending such integrated natural

resources surveys to the remaining areas of arid region. To accomplish these more efficiently, a substation of CAZRI in Kutch region has been approved in VIth plan. Priority will be given for undertaking such studies in Gujarat, Haryana and Punjab and arid region of the peninsular India in that order.

13.1.4 Although much of the resource information is being collected currently by several organisations such as CAZRI, GSI, Botanical Survey of India, Zoological Survey of India, ONGC and Central and State Ground Water Boards, National Bureau of Soil Survey and Landuse Planning and National Bureau of Plant Genetic Resources, ISRO and National Remote Sensing Agency, much of the arid and semi-arid regions is still inadequately mapped. Vitally important, at a time of world food and energy shortages and of spreading environmental deterioration, is the need to monitor the changing conditions of their natural domain to forecast crop yields, to detect erosion of land and pollution of water to recognise alterations in landuse, to give early warning and assess damage of natural disasters and to observe many other aspects of environmental change.

13.1.5 In the long evolution of techniques for resources information gathering, the first earth resource survey satellite (Landsat I) launched by NASA in July 1972 represented a major technological advance.

13.1.6 The new element in this technology is the combination of two recent technical innovations - the use of space platform instead of aircraft and the use of multispectral sensor instead of photographic camera. The satellite data are transformed into two types of products - photo imagery in film or print form and computer analysis are able to extract information useful for a broad range of resources disciplines and management requirements. The details of Landsat satellite system and its applicability for various purposes are given in Appendix.

Landsat reception stations and data distribution centres are now operating in several countries including India at Hyderabad and manned by the National Remote Sensing Agency.

13.2 ENVIRONMENT MONITORING AND PROBLEM SOLVING

13.2.1 The need for continuity of data collection and in some instances for great rapidity of data collection and analysis, have become more manifest in recent years with increased understanding of the impact that environmental factors have on the development process and on human welfare. There is now a growing appreciation of the need for monitoring natural systems - forests arid lands - both to anticipate natural and man made disasters and to deal with their consequences. Some disasters are slow in the making such as soil erosion, siltation, waterlogging, desertifications, others are sudden brief and less predictable such as flood, earthquake, insect infestations. To this end and as part of "Earth-watch Monitoring system" mapping needs to be undertaken to detect change in certain land classification in order to assess critical problems arising from agriculture and land use practices. The classification ideally recommended for such mapping include urban areas, desertification areas, deforestation and forestation areas, coastal zones, irrigated and non-irrigated areas etc. Landsat multidate scenes would prove very useful in such investigations.

13.3 PROCESS OF DESERTIFICATION MONITORING

13.3.1 The following are the parameters indicative of the various features to be observed in a time sequence in the field and on aerial photo or satellite imagery.

i) Moving of dunes
ii) Deflation of fine material
iii) Sand cover and beginning of sand accumulation
iv) Enlargement of rock outcrops or indurated horizons on surface caused by erosion
v) Enlargement of bare areas because of sealing on soil surface
vi) Salinisation
vii) Water erosion

13.3.2 Impact of the processes :

i) Degradation of vegetation
ii) Yields of crops of pasture decreasing
iii) Changes in water balance
iv) Frequency of dust storms

13.3.3 Factors causing the processes :

i) Climatic changes

ii) Human and animal pressures

13.4 APPROACH TO UNDERTAKING MONITORING ACTIVITIES

13.4.1 The approach to monitoring the phenomena on the earth's surface usually requires three sequential types of activities namely (i) the identification and location of the areas to be monitored (ii) the survey of present condition in those areas and finally (iii) the repeated observations of those areas which constitute the monitoring proper.

1. The identification and location of the areas :

In order not to overlook current knowledge and activities, it will be necessary to consider the available information mainly in the literature, but also available from appropriate research institutes and other relevant sources.

Using maps and documents on climatic, vegetation, soils etc. as well as remote sensing data, the first step will be to trace the boundaries of arid and semi-arid areas in the region under consideration.

Having determined and mapped the boundaries of the macro-areas, it may greatly simplify subsequent steps if those boundaries are transferred to satellite imagery in the form of a mosaic of the entire area, which essentially constitutes a photo-map. Such photo-mosaics can be prepared relatively cheaply from Landsat (either ban 5 or 7) black and white imagery in convenient scale of 1:1000,000 or 1:250,000.

To facilitate selection for monitoring, the areas thus delineated could well be sub-divided on the basis of various sources of information into classes of desertification and degree of socio-economic impact. Thus an area classified as having a high degree of active desertification with a high socio-economic impact would be clearly self-selected for monitoring whereas an area with a moderate degree of desertification and of low socio-economic impact would have a much lower priority.

2. Survey of present conditions and provisions of a Data Base for monitoring :

Planning for monitoring involves a survey of present conditions which must include consideration of the processes which are currently leading to desertification. Among these may be climatic changes, soil erosion, depletion of water table, removal or depradation of vegetation by grazing and or cultivation pressure or poor land management practices.

Having determined the causes of desertification either from existing information or by low intensity multi-stage sampling on the ground and aided by aerial photographs and satellite imageries, the factors to be surveyed in order to monitor desertification process or their onset can be identified.

Surveys are envisaged at map scales between 1:5000 to 1:10,000 depending upon various factors including the nature and size of the areas selected and the need to execute remedial or preventive measures in view of the socio-economic implications. In places where good topographic maps are not available, enlarged Landsat imagery possibly annotated with some planimetric detail not readily visible, may be used as a base map. In any case upto data base map at selected scale will be required for the initial surveys.

Available and required information must influence the determination of the scale at which the survey of each significant factor should be carried out.

In addition there are likely to be factors such as the level of groundwater and population growth (both human and livestock) for which statistical recording by geographical coordinate will be more appropriate than mapping alone. This in turn requires consideration of the desirability of establish ing a data bank to store, manipulate and retrieve the survey and subsequent monitoring data - decision which should preferably be taken at the outset since it will affect the presentation of data to be collected.

Another implication of the scale of survey for different factors is the method to be applied. Relatively small scale vegetation mapping

TABLE 2

CROPPED AREA AND ITS DISTRIBUTION UNDER PRINCIPAL CROPS IN DIFFERENT ARID DISTRICTS

(Unit : 000 hectare

Sl. No.	Districts	Gross cropped area	Jowar		Bajra		Wheat		Barley		Other Kharif pulses		Gram	
			Area	% Area to jowar to total cropped area	Area	% Area of Bajra to total cropped area	Area	% Area of Wheat to total cropped area	Area	% Area of Barley to total cropped area	Area	% Area of other kharif pulses to total cropped area	Area	% Area of gram to total cropped area
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
						(Rajasthan 1977-78)								
1.	Barmer	1,497	1	0.07	879	58.72	10	0.67	N	-	171	11.42	1	0.07
2.	Bikaner	796	1	0.13	215	27.01	5	0.63	N	-	293	3.64	1	0.13
3.	Jaisalmer	205	4	1.95	146	71.22	1	0.49	N	-	N	-	N	-
4.	Jodhpur	1,170	10	0.85	555	47.44	37	3.16	1	0.08	234	20.00	8	0.68
5.	Nagaur	1,171	51	4.35	490	41.84	47	4.01	12	1.02	244	20.84	34	2.90
6.	Churu	1,302	N	-	407	31.26	1	0.08	N	-	367	28.18	107	8.22
7.	Jalore	681	3	0.44	239	35.09	47	6.90	4	0.58	65	9.98	11	1.62
8.	Jhunjhunu	541	N	-	189	34.94	15	2.77	10	1.85	135	24.95	112	20.70
9.	Sikar	533	N	-	170	31.89	23	4.32	20	3.75	160	30.02	38	7.13
10.	Pali	599	21	3.51	90	15.03	90	15.03	35	5.84	34	5.67	32	5.34
11.	Ganganagar	1,702	2	0.12	105	6.17	263	15.45	11	0.65	59	3.47	522	30.67
12.	W. Rajasthan	10,197	93	0.91	3,485	34.18	539	5.29	93	0.91	1,762	17.28	866	8.49

may use satellite imagery in association with air photos and ground sampling. Detailed landuse may be mapped from small scale high quality aerial photos (colour infrared dia positives) while yet other factors like groundwater levels can only be surveyed on the ground.

Since all the considerations discussed above are clearly inter-related they should be approached holistically when planning the survey of present conditions.

3. Monitoring :

Essentially monitoring will consist of repeated surveys of the type undertaken to determine the present condition and therefore it will be necessary to determine the interval of such repeated surveys. Very short or very long intervals are likely to be irrelevant e.g. daily weather pattern or major changes in landform. Relevant interval for periodic monitoring will be determined by the rate at which various elements of the desertification process change to a significant and detectable degree.

Earth observation satellites presently provide cover at 9/18 days interval for areas covered by a regional receiving station. Another monitoring facility is provided by the capability of the earth observation satellite to act as Data collecting platform by receiving transmissions from automatic recording stations on the ground and relaying those to a central data collection facility.

The capacity for monitoring at a range of interval is, therefore, considerable and able to accommodate the needs likely to emerge as a function of the rates of changes to be observed. To determine the optimum monitoring procedure is evidently a complex matter, best approached by making relatively frequent and large-scale observations and progressively refining these on the basis of both of experience and of changes in the factors being monitored.

13.5 AGENCIES INVOLVED

13.5.1 National Remote Sensing Agency, Hyderabad : Prior to 1979, India and other South Asian countries looked forward to NASA/EROS Data Centre Sioux Falls, USA, for procuring Landsat data products in the

form of photo-imageries and computer tapes. However, the Earth receiving station at National Remote Sensing Agency at Hyderabad began taking test data from Landsat in August 1979. The station is fully operational from early 1980 and NRSA by agreement with NASA (USA) will be sole supplier of Landsat MSS data to all user agencies not only in India but also in whole South Asia including Bangladesh, Sri Lanka, Burma, Indonesia, Malaysia etc. A large number of application projects are currently in progress at NRSA including inventory of natural resources, water and soil.

13.5.2 Indian Space Research Organisation : ISRO is already involved in earth resource inventory in arid and semi-arid regions. For the period from 1972 to 1979 ISRO is also dependent on EROS data Centre,USA for Landsat MSS data and from 1980 onward it will be dependent on NRSA, Hyderabad. However, ISRO has programmes of launching its own Earth Resources observation satellite but the photo-imageries produced from it at present have a coarse resolution of 80 m only which is a limitation. However, for certain specific studies finer resolution of 40 m is called for. To this end, the proposal of ISRO to have 40 m resolution images in their new satellite to be launched in 1984-85 would be extremely valuable. Besides, it will be useful if IR Band is added to the sensors (if not already designed) for monitoring environmental conditions and mapping surface moisture, geological and geographic features. The proposal for studies on monitoring of dust storms and biomass changes can be considered jointly with CAZRI. ISRO has good softward facilities which are available for user agencies.

13.5.3 Institute of Agricultural Research Statistics (IARS), New Delhi : As mentioned earlier there is need for data bank to store the information for retrieval either for consultation as reference point or updating the information. The IARS, New Delhi which is centrally located has the facilities and expertise for computer based data storage and retrieval which are freely available for all user agencies.

13.5.4 Department of Geo-engineering, Andhra University, Waltair (A.P.) : Digital image processing capability has been established through a RESPOND programme for integrated resource evaluation studies.

13.5.5 Geological Survey of India : This organisation with its immense infrastructure is already concerned with environmental monitoring which may be further strengthened.

13.5.6 Central Arid Zone Research Institute : It is already involved in monitoring the physical, biological and social indicators of desertification of Western Rajasthan and neighbourhood. The resolution of the recent ESCAP Workshop held in Jodhpur from 20-23 October suggested CAZRI as one of the Centres of excellence for imparting training in the field of desertification monitoring and control. The "Transnational project to monitor desertification process and related national resources in arid and semi-arid areas of S.W. Asia" initiated by UNEP but later lapsed, has also been suggested for revival by ESCAP workshop and CAZRI is an important centre in this programme. For aforesaid reasons, there is need for strengthening the infrastructure at this Institute.

13.5.7 Central Ground Water Board : Shall associate in monitoring the ground water resources from time to time through network of four hundred observation wells which they possess in Western Rajasthan. This organisation has plans to investigate the degree of exploitation of ground water on block basis in whole of Western Rajasthan.

13.5.8 The Rajasthan State Ground Water Board : It can contribute substantially in enhancing the status of art in ground water hydrology in the arid regions and thus complement the ground water resource information generated by foregoing agencies.

13.6 FUTURE RESEARCH PROGRAMME

(i) Besides the sites selected in Western Rajasthan and Haryana by CAZRI, there is need for identification and location of areas to be monitored in other states vulnerable to desertification.

(ii) To extend the programme of integrated natural resources surveys to other areas of arid zone in order to establish a sound data base and reference point.

(iii) To monitor the parameters indicative of various features in time sequence in the field and photo imagery such as Moving of dunes, Deflation of fine material, Enlargement of rock outcrops or indurated horizons, Salinisation and Water erosion.

(iv) To assess the impact of the processes on (a) degradation of vegetation, (b) yield of crops, (c) change in water balance and frequency of dust storm.

(v) To analyse the factors causing the process like (a) climatic change, (b) human and animal pressures.

(vi) To establish computerised data storage and retrieval information systems with ground referencing in centres of arid zone research and to further strengthen institutions already having this facility.

LANDSAT AND MSS DATA CHARACTERISTICS

The Landsat data are multispectral, temporal, synoptic and near orthographic. Thus they have properties not previously available in photographs taken from aircraft. The limitations of the Landsat data in the present state of art include resolutions lower than that of aircraft imagery, atmospheric attenuation and since data are taken at fixed intervals there is no chance of avoiding cloudy and stormy weather and one has to be selective in the choice of imageries.

A complete description of the Landsat system and multispectral scanner characteristics is given by NASA (1972) and Taranik (1979). A summary of some of the essential features is given below :

Landsat - 1 (initially designated as ERTS-1) was launched on July 23, 1972, and was retired from service on January 6, 1978. The continuity of the Landsat-type coverage is currently being maintained since an identical Landsat-2 was launched on January 22, 1975, and Landsat-3 was successfully launched on March 6, 1978. Landsat-3 is identical to Landsats 1 and 2 with the addition of a thermal sensor channel.

The Landsat operates in a circular sunsynchronous near polar orbit at an altitude of approximately 920 km (570 miles). The satellite circles the earth every 103 minutes completing 14 orbits per day and viewing the earth every 18 days. The orbit is selected and timed so that each satellite ground trace repeats its earth coverage at the same local time every day and repetitive images (of the same area in different dates) are maintained to within 37 km. The images produced from the Landsat oncompass an area approximately 185 km x 185 km (115 by 115 miles) or 34,225 sq.km. or 13,225 sq. miles.

Fourteen southbound day time orbits are covered by Landsat during a single day. The northbound orbits cover the dark side of the earth. Rotation of the earth shifts the orbit paths westward

each day so that at the end of 18 days, or 252 orbits, the earth has been covered and the cycle begins again. The polar areas above latitude 81° are the only regions not covered by Landsat orbits. There is 34 per cent side lap of the 185 km wide image swaths generated on successive days. The sidelap decreases to 14 per cent at the equator and increases to 70 per cent at polar latitudes. The sidelapping portions of adjacent images may be viewed stereoscopically also.

From January 1975 through mid 1976 Landsat 1 and 2 had identical orbit patterns that were offset by nine days. By combining the two sets of images, complete coverage could be obtained every nine days.

The landsat multispectral scanner responds to earth reflected solar radiation by means of a line scanning device that uses an oscillating mirror (13.62 Hz frequency)to continuously scan perpendicular to the satellite track. Six lines are scanned simulataneously in each of the four spectral bands for each mirror sweep. The satellite's forward motion provides the along track progression on the scan line. The upward radiation is sensed simultaneously by an array of six detectors in each of the following spectral bands :

Band	Wave Length	Remarks
Gamma ray	0.03 Um	Incoming radiation from the sun is completely absorbed by the upper atmosphere and is not available for remote sensing Gamma radiation from radioactive minerals is detected by low-flying aircraft as a prospecting method.
X-ray	0.03 to 3.00 Um	Incoming radiation is completely absorbed by atmosphere. Not employed in remote sensing.
Ultraviolet UV	3.00 to 0.4 Um	Incoming UV radiation at wave lengths 0.2 Um is completely absorbed by zone in the upper atmosphere.
Photographic UV	0.3 to 0.4 Um	Transmitted through the atmosphere. Detectable with film and photo detectors, but atmospheric scattering is severe.

Visible	0.4 to 0.7 Um	Detected with film and photo detectors. Includes earth reflectance peak at about 0.5 Um.
Infrared, IR	0.7 to	Interaction with matter varies with wave length. Atmospheric transmission windows are separated by absorption bands.
Reflected, IR	0.7 to 3 Um	This is primarily reflected solar radiation and contains no information about thermal properties of materials. Radiation from 0.7 to 0.7 Um is detectable with film and is called photographic IR radiation.
Thermal, IR	3 to 5 Um 8 to 14 Um	These are the principal atmospheric windows in the thermal region. Imagery at these wavelengths is acquired through the use of optical mechanical scanners, not by film.
Microwave	0.3 to 300 Um	These longer wavelengths can penetrate clouds for fog. Imagery may be acquired in the active or passive mode.
Radar	0.3 to 300 Um	Active form of microwave remote sensing.

The line scanned by the first detector in one mirror sweep lies adjacent to the line scanned by the sixth detector with the previous mirror sweep. The detectors analog output signals are sampled, digitized and formatted to a 15 megabit/sec continuous data stream and transmitted to an earth receiving station.

The continuous strip MSS data are converted into "framed" imagery with a 10% overlap between frames. Photographic images and computer compatible tapes (CCTs) of digital data are the output user products. The area of one Landsat image is recorded by the satellite in 28.7 seconds. Each image consists of 2340 parallel scan lines averaging 3220 resolution elements each. The resolution elements or "picture elements" are more commonly called "pixels". The effective spatial resolution of the Landsat MSS data (pixel size) is 56 m by 79 m (184 by 259 ft) or 0.4424 ha (1.093 acres).

Typical signatures on color composite landsat images are as follows :

Vegetation	-	Red
Water	-	Dark Blue
Suspended sediment	-	White to light blue
River beds	-	Yellow
Bare soil	-	Blue
Aeolian sand	-	White to yellow
Cities	-	Blue
Clouds and snow	-	White

Black and White Panchromatic Photography :

Black and white photography is unexcelled in utility for stereoscopic viewing and as a continuation of previously recorded sequential images. This old standby has been around for so long that it tends to be the standard : every other sensing device is measured by it. It can be used with rapid return and standardized techniques and at low cost.

Colour infrared photography (CIR) :

There is little doubt that CIR is useful in the monitoring environment. Recent break throughts in filter combinations and processing techniques indicate that it will remain so far some time to come.

Despite the above, CIR is unsurpassed in its ability to record healthy vegetation, penetration haze and differentiate patterns. While not a solution to all photographic or remote sensing problems, CIR has become the single most important film for research on the urban environment.

Thermal infrared sensing :

Thermal infrared sensing (TIR) is another important tool. TIR rarely can be used for detailed landuse analysis, economic activity or similar urban studies. The most common use to date is for environmental impact, energy budget and pollution detection. Although cloud interference is a handicap, TIR is both a day and night sensor. Most operate in the 8 to 14 um band, but some use the 3 to 4 um band. In

addition to the above (detection of environment, energy and pollution) TIR has potential for studies such as housing abandonment, traffic flow, flood-hazard detection, air movement monitoring and several other such items.

The disadvantage of using TIR is the relatively high cost. Most TIR sensors are optical methanical scanners, where detectors require super-coding and both initial and maintenance costs are high. As a result, the purchase or lease of an optical mechanical scanner is considerably higher than that for sensors in the visible and near visible ranges.

The capabilities and limitations of Landsat data in the major application sectors are given below :

Agricultural Production :

Crop acreage - 95% accuracy in large simple areas; 75 to 80% in complex areas (small fields, intermingled crops). Although inadequate for acreage estimation, yet if offers a base upon which an agricultural sampling system can be designed.

Yield forecasting :

Does not by itself provide an acceptable substitute, but gives promising results used in modelling procedures in combination with meteorological and other data.

Soil survey :

For reconnaissance level and land system surveys; with computer enhancement it has been shown capable of detailed soil mapping at scales upto 1:24,000.

Rangeland Management :

Can provide useful inventory data but can not identify all vegetation types. Monitoring of significant vegetational data and 9-day frequency of Landsat coverage.

Forest Management :

Effective in improving sampling procedures for estimating timber volume in monitoring forest cutting of clear cut type and or monitoring depletion of forests.

Water resources management :

Highly reliable in locating surface water. Useful in assessing major watershed characteristics that affect runoff. Effective in delineating large flooded areas. Can provide significant input to water consumption models at irrigation projects. Can identify geologic features that indicate promising areas for ground water exploration like palaeo channels.

Geologic survey and mineral exploration :

Contributes to improved geologic mapping. Unique capability to disclose large geologic anomalies which indicate possibilities of mineralization.

Cartography :

Useful in correcting and updating existing maps at scales of 1:250,000 and also help indicate areas where higher resolution imagery from aircraft is required; provides data to map uncharted areas quickly and cheaply.

Land use :

Urban & Regional Planning : Useful for regional planners in providing frequent update on gross landuse change among categories such as agriculture, wet lands, forest built up areas. Synoptic view of large areas particularly useful for planning development.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
						Haryana (1979-80)								
.	Hissar	6,320	1.26	6.96	1.42	9.64	-	-	-	-	-	4.58	4.58	85.78
2.	Sirsa	4,270	1.19	5.15	0.46	6.80	-	-	-	-	-	0.93	0.93	92.27
3.	Bhiwani	5,090	0.98	5.12	2.78	8.85	1.57	-	-	1.57	-	0.98	0.98	88.60
						Gujarat (1972-73)								
1.	Kachchh	45,612	2.25	2.45	38.35	43.05	1.35	0.01	39.38	40.74	1.92	1.82	3.74	12.47
2.	Jamnagar	10,144	7.43	6.21	12.19	25.83	7.69	0.01	2.96	10.66	3.69	1.80	5.49	58.02

CHAPTER XIV

14.0 HUMAN FACTOR IN ARID ZONE DEVELOPMENT

14.1 INTRODUCTION

14.1.1 The general problem of Indian Arid Zone is essentially one of the human ecology since arid lands in this country are not virgin but have fairly high densities of population. Over exploitation by man of water, plant and land resources has disturbed the delicate ecological balance. Over-grazed lands, shrinking forests and eroded agricultural fields show the imprints of man's activities of his environment. The way of life of the people in the region and their sources of livelihood have chiefly been conditioned by disturbances in ecological balance due to the severity of the arid climate. The form and pattern of settlements in this tract is quite distinct as compared to those in other parts of the country. Besides, a sizeable proportion of the population here leads a migratory, semi-nomadic or nomadic life. The density of population, though low as compared to other parts of the country, is high enough by arid zone standards. The rate of growth of population is relatively higher, while the literacy rate and its level are low. People, by and large, are traditionalists and the socio-religious beliefs often override prudence. The majority of the rural workers are tied to an outmoded agriculture. The agricultural holdings are large but the production from the land is low and extremely unstable, depends as it does on erratic pattern of rainfall. The livestock population exceeds human population and inspite of the presence of some of the best breeds of livestock, production in the livestock sector is meagure because of malnutrition. Nomadism, adopted as a way of life to cope up with the unfriendly climate, is in a dying phase, due to improved communication facilities and to other changes brought about by the successive Five Year Plans.

14.1.2 In the past there has been an unfortunate neglect of the social dimensions of the problems and most scientists believed that the objectives were achieved if they were just able to acquire knowledge about the resources and their optimum use and development in an arid environment. Recognising this the Division of Human Factor Studies was established at CAZRI Institute in 1959. Socio-economic surveys of settled,

semi-nomadic and nomadic population in relation to demographic structure, caste differentials, households characteristics, occupational structure, production pattern and livestock population have been conducted. Nature and extent of interaction between man, land, livestock and environment and extent of symbiotic relationship between settled and nomadic groups have also been brought out.

14.1.3 New knowledge has also been developed by conducting research on the nature and extent of adoption of different types of agricultural innovations, channels of communication involved in the process in diffusion; socio-economic consequences of canal irrigation in an arid areas in the context of population changes - immigration, growth and density of population, changes in land use parameters, forestry development, water level; changes in agriculture and livestock; etc. Studies on biotic factors and desertification, a quantitative analysis of desert spread, an opinion survey of desertification, traditional perceptabilities and social aspects of desertification were also carried out. Projects on social, economic and historical perspectives of land reforms and impact of drought on the social and economic structure of the population inhabiting arid zone of Rajasthan were also taken up.

14.2 FINDINGS

14.2.1 Population characteristics

14.2.1.1 Spread over an area of 208 thousand sq.kms. the Rajasthan arid zone (consisting of 11 districts of western Rajasthan) has a population of 13.40 millions (1981). The region has an average density of 64 persons per sq.km. and is one of the most thickly populated deserts of the world. The growth rate of population (1901-1981) in the arid zone of Rajasthan (excluding Ganganagar district where the rise has been mainly due to immigration of population) was 249% as compared to the Rajasthan State (231%) and of the country as a whole (187%). Similarly, within the arid zone of Rajasthan the percentage increase in population during the period 1901-81 has been 279%, 262% , 219% in the region receiving annual rainfall of less than 12" (excluding Ganganagar district), between 12"-16" and above 16", respectively.

14.2.1.2 The present age and sex composition of population and their marital status further revealed high potentialities of expansive future

growth of population. Being fully aware of the dangers of getting wiped out due to high mortality, specifically during famine periods, the arid zone society had built in high fertility norms in their culture. Though the mortality, specifically the infant mortality has been controlled to a significant extent the high fertility norms still continue. Early marriage and begetting of children are integral parts of the social ethos of these people. Any deviation from the established norm is looked down upon as an aberration and as wholly incompatible with the social fabric of the society. Divorc is a rarity, if not altogether unknown, and widowhood soon culminates in remarriage except for among Rajput, Brahaman and Mahajan castes. If the birth rate does not fall, the present gap between births and deaths will further widen and the region will be faced with an inevitable population explosion. Family planning programmes undertaken in the region after Independence have yet to make any inroads, due mainly to their inherent weakness in terms of negligence of culture variables which are mainly responsible for creating chain of resistances. It may be emphasised that the obstacles to small family norms are not primarily technological but sociological. Unless the ancient prejudices, deeply ingrained beliefs and traditional cultural practices are taken into account it will deprive us of the sources of support to any family planning programmes and lead us to centres of resistance.

14.2.1.3 Raising the age of marriage, strict enforcement of laws regarding the performance of death ceremonies at which child marriages are organized and the creation of employment opportunities for women as well as giving women preference with regard to certain type of employment, developing an intensive education programme are some of the measures which need attention. By and large, the external migration has played a relatively insignificant role in the population dynamics in the arid zone. Immigration has been very limited because of the absence of the factors like productive lands, large scale industries and mineral production. Inspite of the heavy push factors viz. excessive overcrowding on the already over-saturated lands etc. there has not been much of outmigration due mainly to the lack of pull factors (like absorption in big industries or other urban vocations) and also due to the backwardness of people, poor means of communication and the sway of the social institutions like the joint family system, caste system, early marriage, and the illiteracy and conservatism of the people (Malhotra, 1977). For instance, the percentage of immigration from other states to Rajasthan (1961 census) worked out

at 4.90 per cent of the total population while that of outmigration from Rajasthan to other states worked out at 5.62 per cent. Thus, the net outmigration had been only 2.14 per cent of the total population. Since the arid areas are often in grips of drought and famine huge temporary migrations are resorted to and it is felt necessary to draw bold migration policies and provision of effective employment to the people during migration.

14.2.2 Settlement and housing

14.2.2.1 It is largely due to the distinct physical and cultural characteristics of the desert, like the duny character of the landscape, the scattered location of water sources, the socio-cultural heritage of certain castes, the Jagirdari system and the traditional custom of bringing in tenant-cultivators, that the majority of the villages have either o scattered homesteads or have both compact and scattered homesteads. The society being patrilenial and patrilocal, the agnatic ties have much greater influence on the proximity of settlements. Only the indigenous flora and the other locally available materials are used in the construction of houses due to the inherent difficulties of the hietherto prevalent poor communication systems coupled with the poor economic status of the people. People living in scattered homesteads (dhanis) have greater economic advantages through close and continuous contact with the land, while the people living in scattered compact settlements at the core enjoy a richer social life. The nature of activities and type of social relationships of the people have been conditioned by the form of the settlement. The web of social relationships is confined within the cluster of dhanis. Housholds living at the core make greater use of the community facilities, while those living in the dhanis are inadequately covered. There is much smaller use of community facilities and the network of services such as education and health care normally do not reach the dhanis. Intensive surveys and research on concerted basis to bring about improvement in human settlements which are compatible with socio-cultural values and which make better use of local materials to make the traditional abodes more confortable is an immediate necessity (Malhotra 1978).

14.2.3 Food and Dress pattern

14.2.3.1 The staple food of the rural folk is bajra (pearl millet), the common preparation from which is sogra - the backed bread and the dal

(Pulses). Additionally, the air dried seeds and pods of locally available trees and shrubs are used for preparation of curry. Ordinarily, the females cook the food and first serve to children, later to the other male members and then the females tale food in the end. Due to prevalence and occurrence of frequent drought, however, bajra ia also not always available in sufficient quantity. The farmers, therefore, adjust their food according to the grain availability e.g. during loan wears instead of bajra bread the following is eaten which satisfies hunger by lesser consumption of grain. This is said to affect health but is a means of survival.

1.	Rabdi	-	Bajra flour and butter milk is cooked and this provides 50% saving in the consumption of the foodgrains.
2.	Khich	-	Ground bajra grains and moth are cooked in water and it was said the consumption of 5 kg grains is reduced to 2 kg grains.
3.	Doh	-	During the extreme loan period, when even butter milk is not sufficiently available, the small quantity of butter milk is kept in the sun and allowed to ferment and this is used with cooked ground bajra grains. The continuous consumption of such food, however, supposedly affects the eyes and causes night blindness.

Similarly, in times of scarcity the seeds of Phroot - a prickly grass is ground and used as a food.

14.2.3.2 The dresses worn by men and women are very colourful and of variegated designs. The menfolk wear long flowing shirts made of cotton or wool tied by laces known as Angrakhi. The dhoties are quite common and the headgear is made of variegated colours ranging from plainly dyed to those profusely covered with intricate designs. Women wear tight fitted blouse called choli often also studied with small circular mirror pieces. The headwear is very colourful known as Odhini and this also covers partly the angrakhi. The rural females wear many oranaments both of silver and gold on their feet, ankles, neck, shoulders, ear, forehead and head. Large Bor (a leaf shapped disc helped by the chain worn round the head worn by the women are the sign of wedlock. Menfolk too, among certain castes and of a higher economic status wear ear rings known as Murkees. The material, quality and quantity of

material however, depends chiefly on the socio-economic status of the family.

14.2.4 CULTURAL INTEGRITY AND RESOURCES USE

14.2.4.1 Resource use being the decisive factor of the pattern of their living, the population of Rajasthan's arid zone is divided into two major groups, viz., the nomadic and the sedentary. The pastoral nomads inhabited the extreme arid areas considered unsuitable for cultivation and engaged themselves in animal husbandry, supplying livestock and livestock products to the sedentary population (which inhabited slightly better areas permitting cultivation of cereal and non-cereal crops) in exchange for the cereal foods that were produced mainly by the agricultural castes. The other types of nomads also catered to the needs of the sedentary population in return for grains (Malhotra, S.P. 1971). The sedentary population, by and large, lived in villages which were self-sufficient units except for the materials supplied by the nomads operating in the region.

14.2.4.2 Each type of the two populations was further broadly grouped on the basis of the traditional occupations. There was a difinite division of labour, a patterns of exchange relationships and a distributive use of the ecosystem within the sedentary population. Based on their functional specialisation, the nomads could be categorised into four groups viz. the pastoral nomads (Raikas, Sindhis, Parihars, Bhill ochs etc.) b) the trading nomads (Banjaras, Ghattiwala Jogis and Gowarias) c) artisan nomads (the Gadoliya Lohars, Sansis and Sattias) and d) miscellaneous types of nomads (Nats, Kalbeliyea Jogs).

14.2.5 PASTORALISM AND BALANCED USE OF ECO-SYSTEM

14.2.5.1 The pastoral people, inhabiting the Rajasthan desert have been carrying on livestock breeding for generations and have contributed to the economy of the region by way of providing milch cattle, ghee, wool, mutton, etc. to the sedentary as well as to other nomadic pollutions. They inhabited and utilised the areas which were relatively more arid and less suitable for cultivation and hence they rightly utilised these lands as pasturage for their livestock. Based on their centuries of experience, these nomads had developed unique methods of centuries of experience, these nomads had developed unique methods of water harvest-

ing, for the most effective utilization of the grazing lands and also for ensuring their revival and growth during the succeeding years.

14.2.5.2 The villages in the arid zone encompass a big area often to the extent of 30-40 sq.km. in the centre of the village is Abadi (settlement). In case one goes to the village during the rainy season, it would seem as if the village is deserted or uninhabited. In fact, with the start of the rains, the population divides into different caste groups and disperses to their tobas (small dug out ponds) alongwith their livestock. These tobas are situated within the confines of the village boundary but out side the settlement proper. As of the one toba where water and fodder still might be available, and by convention they have to be allowed the facility of using the water and grazing resources there. It is only when the water in all the tobas gets exhausted that the entire population alongwith their stock return to the village proper and then use the water in the village tank and the lushy growth of grasses around the village. It has been observed that in many cases there was a scope of digging the toba deeper so that it could store more water, but none was prepared to adopt this. The reasons for this reluctance, evidently was the convention of allowing all to come and use not only water but also the grazing resources around the toba. Deepening of the toba would, therefore, put additional pressure on the grazing lands which may not allow regeneration of the grasses, etc. This system of rotational and deferred grazing with the indigenous expertise ensured the restoration of the vegetation in the succeeding year.

14.2.5.3 It is only in the scantly rainfall years that the livestock breeders moved their livestock to the adjacent semi-arid and humid regions where the winter crops have then been harvested and the left-ever stubbles made available for the animals, to graze on. Enroute, the livestock breeders often sell milk, ghee and animals to the sedentary population. For penning the livestock in the fields during night the field owners would even provide them food and some money as their fields get the benefit of manure. The livestock would return home with the start of the monsoon and again disperse far and wide on the tobas within the village boundary.

14.2.5.4 These nomadic movements were evidental, not chaotic, rather there appeared to be sufficient logic in these movement for pattern of resource use geared not only to provide adequate water and forage to the livestock but also for permitting regeneration of the vegetation.

14.2.5.5 The second and the third important category of the momads also had definite cycles of their movements in small kinship bonds, leading a corporate life, following a doctrine of collective responsibility, their own system of social control and mutually set traditional relationships of mutual dependence and complementary roles in the economy of the sedentary population.

14.2.5.6 Detailed rehabilitation schemes have been prepared for the Banjaras (the trading nomads), the Gadoliya Lohars (the artisan nomads) and for the nomadic cattle breeders of the Anupgarh Pugal region of Western Rajasthan, keeping in view their present cultural values, kinship structures and other important social and economic factors. Studies have shown that the Gadoliya Lohars desire sedentarization in small agnatic groups within their own choklas. Sedentarization programmes on this basis will ensure the continuity of their symbiotic relationship with the sedentary population through marketing facilities for the articles fabricated by the nomads. Settlements in small, scattered groups will make it easier for the Government to allot land for cultivation to the Gadoliya Lohars. Moreover, such sedentarization should rule out and any change of funds occurring amongst the households of different clans. The Gadoliya Lohars should, therefore, be settled in bands of small kinship groups within their own choklas or their present areas of movement.

14.2.5.7 Nomadic Banjaras should be sedentarised tandawise i.e. in small kinship groups. Settled Banjaras work in agriculture and animal husbandry, trading in cattle and salt. The tanda should be treated as the unit for settlement purposes. Any approach to the Banjaras should be through their Mukhias who are not only their best spokesmen but also the best media for communicating with them.

14.2.6 LAND AND RESOURCE UTILISATION BY SEDENTARY POPULATION

14.2.6.1 Like the resource use by nomads the sources of livelihood and the way of life of the sedentary population had also been conditioned

by the disturbances in the ecological balance owing to the vagaries of the climate. Agriculture in the arid areas has always been a big gamble and the droughts and famines namely akal (great famine), Jalkal (scarcity of water), tinkal (scarcity of fodder and trikal (scarcity of fodder, water and grain) have been of common occurrence in the region. The desert dwellers had, therefore, evolved tenancious means and adjustment mechanisms to cope up with such situations. A few case examples are provided below :

14.2.6.2 Over 80 per cent of the population inhabit rural areas. Approximately two-thirds of the total population constitutes the non-working class. Such high percentage of economically inactive population may largely be attributed to the high concentration of population in lower age groups. The occupational distribution of the working population revealed that cultivation and agricultural labour formed the main occupation of over three-fourth of the total workers. Another major occupation followed by the workers is the operation of household industries and manufacturing other than household industries. Trade, mining and other services formed the chief occupation of a small percentage of earners only. Animal husbandry is, however, often followed as a subsidiary occupation by the majority of the households and in certain pockets (where the aridity index is relatively high), such as the Anupagarh-Pugal region, it formed the main occupation of ever-two thirds of the total workers.

The villages in the arid zone had a heterogenous caste composition and the village society enjoined upon each caste to perform certain functions which were inter-dependent and complementary to each other, thereby weaving the economic system into a single integrated unit. Traditional occupations formed the basis of caste distinctions and of the economic system and its consequent bonds of mutual obligations. On the basis of the traditional occupations, the castes in the villages may be grouped into five broad categories, viz., (1) Agricultural castes like Jats, Bishnois, Rajputs, etc. (2) Castes serving the needs of agriculturists, like Suthars, Lohars, Bambis etc. (3) Caste serving the needs of the community with regard to the socio-religious ceremonies like Brahmins, Sads, Swamies, Sewaks, Dakots and Dadis, (4) Castes serving the other needs of the community like Nais, Darjis, Sonars,

Khatris, Kumhars, and Sansis, and finally (5) Castes having animal husbandry as the major occupation, like Raikas and Muslim cattle breeders (Goperas, Kharla, Billoch, etc.).

14.2.6.3 The interdependence of the different castes in the econimic organization of the village becomes more emphasised during occasions of marriages, socio-religious festivals, etc. when each caste has a specific contribution to make. The services rendered by the Suthar, Lohar, Nai, Bambi and Darji castes are governed by what is known as the aat system, under which every family caters to the needs of a group of families for a particular type of service, payment for which is fixed by tradition and made on an annual basis either in cash or in kind, at the time of harvest of crops. The amount to be paid depends upon the quantum of work, families with large agricultural holdings or large number of members generally paying more. Sometimes a part of the service are governed by aat and a part by other transactions.

14.2.6.4 The functional specialization of different castes and communities not only knitted them together through relationship of exchange of the produce and the services but also resulted in as distributed use of the ecosystem. It is only the traditional calling of the pastoral nomads (livestock raising) and of the agricultural castes (tilling land for cultivation) that put direct pressure on the dessert lands while the remaining population mainly catered to the needs of these pastoralists and castes engaged in agricultures for receiving livestock and agricultural products in exchange of services. The socio-economic framework thus provided for a balanced use of the ecosystem for the benefit of the society as a whole.

14.2.7 Mixed Farming

(a) Since the rainfall would not only vary five to ten folds from one year to another, but also during the same year at places just at a few km., from each other. The farmers were never sure of harvesting the grains. Most of them had a subsidiary occupation like livestock raising which at least, ensured their survival. The livestock would also be able to survive on the fodder stalks that might be available in the even of no or partial harvest of grains. Again, as mentioned in the case of the nomads, the livestock raisers among the sedentary population also used to resort to migration to better rainfall areas which provided for their livestock and met their needs for arrival.

more than 70%. But on the wetter side and with heavier soils cropping gets more diversified with bajra occupying 30 to 50% only and jowar, sesamum and pulses making the rest. Cotton and jowar, are the main crops in north in Ganganagar and Hissar. Where winter rains of some significance occur, rabi crops, mainly gram becomes quite prominent. In Bhiwani, Mohindergarh, Hissar, Churu and Sikar, cluster bean has gained immense popularity in recent years. Picture in respect of arid Rajasthan is presented in Table 2 (in page No.7).

2.5 AGRONOMIC RESEARCH AND ITS ACHIEVEMENTS

2.5.1 Encouraged by the success of introduction of high yielding crop varieties/hybrids, a number of coordinated research projects were launched by the ICAR. Of all these projects, AICRP on Dryland Agriculture was one of the largest with 23 Dry Farming Research Centres covering major agro-climatic conditions of which three are located in arid areas (Jodhpur, Hissar, Dantiwara). These projects proved their utility by providing information on various agronomic aspects. Some of the research results concerning dryland agriculture technology for arid zone are presented in next few pages.

2.6 SELECTION OF CROPS AND VARIETIES

2.6.1 Breeding objectives : Millets, pulses and oilseed crops form bulk of the crops grown under rainfed conditions in our country. A critical examination of most of the currently cultivated varieties of these crops on drylands in arid regions reveals that they have been selected for their ability to survive atmospheric and soil drought rather than for productivity. They are poor yielders with a prolonged vegetative grown and hence do not fit into the rainfall pattern of the region. It appears that due to lack of adequate efforts to dovefail the plant breading programmes with other improvements in dryland agriculture in the past the individual practices developed by the scientists for moisture and soil conservation have not found wide adoption because of their marginal impact on productivity. Thus, there is a need to develop suitable plant ideotypes for rainfed agriculture. These have to be designed so as to achieve a desired and balanced combination of resistance to soil and atmospheric drought on one hand, and the plant productivity parameters on the other. It is necessary that a suitable maturity pattern,

(b) The size of land held with the individual households were quite large and was scattered far and wide within several fragments in the boundary of the village. The farmers were generally of the opinion that greater number of fragments of land provided surety for getting some harvest from some plots as they may get rains while others may remain absolutely dry due to the erratic nature of the rainfall.

(c) The above system thus had an in-built provision of leaving the lands fallow during the period these did not get rain. Even otherwise also, the farmers had developed the practice of leaving the land fallow after 4-5 years of its cultivation. This resulted in the land regaining fertility . The fallow lands also provided grazing resources for the livestock which, in turn, provided manure to these fields.

14.2.8 Land holdings

14.2.8.1 The average size of land holding in the region worked out to be 9.9 ha which is almost double the average size of holding in the state. The land distribution, however, is uneven and there is concentration of land holding in the hands of a few richer farmers e.g. only 11.2 per cent households possessed 50 per cent of the total land in the region, whereas 47.3 per cent of households held only 10 per cent of total land. The man to land ratio, is fast declining. The total land available per household was 17.77 ha in 1951, only 14.69 ha and 12.40 ha was available during 1961 and 1971 respectively and only 71.52 ha is likely to be available by the turn of century. Similarly, the total cultivable land available per household declined from 13.72 ha in 1951 to 9.95 ha in 1971 and only 6.03 ha is likely to be available in 2001.

14.2.8.2 As a consequence the farmers are making more and more constant use of the land for cropping thus disturbing the earlier practice of leaving it fallow for replenishing its fertility. The cultivation has also been extended to the marginal and sub-marginal land. Viewing historically it is noticed that the percentage net sown area in arid zone of Rajasthan had been 28.61 in 1951, 41.07 in 1961 and 75.05 in 1971 while the percentage of double cropped area during this period ranged from 0.41 to 1.45 per cent only. The net sown area increased by 44.54 per cent during 1951-61 and by an additional 9.47 per cent during 1961-71 and the area under less intensive uses of land (Barren, cultivable and uncultivable waste lands, permanent pasture and fallow lands)

declined by 16.83 per cent during 1951-61 and further by 6.95 per cent during 1961-71. The overcrowding of labour force on agriculture has therefore, been resulting in the use of land beyond its ecologically capabilities and its productivity has sufficiently declined.

14.2.8.3 Inspite of the poor soil fertility and the scanty and erratic rainfall, cultivation and animal husbandry is the major occupation of the people in the arid and semi-arid parts of Rajasthan. In the region surveyed so far more than three fourths of the workers were engaged in cultivation as their principal occupation.

14.2.9 Land reforms

14.2.9.1 Studies (purohit 1971) conducted on "Social, economic and historical perspectives of land reforms" revealed that with the passage of time (18 years from 1957-58 to 1975-76) the degree of acuteness of concentration of land in fewer hands tended to increase for all caste categories. This shows the tendency towards minimizing the gap between haves and havenots. It thus seems plausible to infer that land tenurial management system and caste structure jointly bred the existing imbalances in the land ownership pattern. It further revealed that a considerable "Social distance" leading to imbalances in land ownership of past. Abolition of Jagirs in arid region of western Rajasthan has attempted to mitigate it. Dhani settlements got momentum after Jagir abolition, pucca houses and farm structure sprang up for the considerations of financial and social security. A marked tendency towards increase in socio-economic status in lower caste groups was revealed owing to land ownership. Excriminal tribes similarly left their anti-social vocations in favour of cultivation. Land reforms thus brought about many significant socio-economic changes in the rural population. This has resulted into reduction in socio-economic disparities.

14.2.9.2 In the eleven districts of arid zone the percentage of loss than 5 acres, 5-15 acres, 15-30 acres and morethen 30 acres of land, comes to 14.52, 29.18, 24.22 and 30.94 respectively. There is hardly any problem of landless labour in the area. However, people who have small agricultural holdings do agricultural labour for which there is a demand during the plaughing and harvesting seasons. Subsistance farming is still largely in vogue.

14.2.9.3 The system of cultivation by rotating and following a proper mix of different crops further provided security in this risk prone agriculture. After following the land, usually guar (Cymopsis tetragonoloba) was grown in the first year and the land was plaughed thrice. This was followed by a mixed crop of Bajra (Pennisetum amerucanum) moth (Vigna acontifolia), moong (Vigna radiata), and till (Sesamum indicum) in the ratio of 20:1:1:1. In the subsequent years the proportion of moth crop was increased as this required lesser fertility.

14.2.9.4 Bajra is the most important kharif crop in the region followed by Guar. The crop yield is, however, poor due to the natural hazards and also due to the traditional agricultural practices still followed in the region.

14.2.10 KHADINS CULTIVATION

14.2.10.1 The desert dwellers had evolved tenacious means to use the conserved moisture by way of cultivation of 'Khadins'. 'Khadins' essentially are natural depressions in the midst of rocky and stony terrains-characteristic of arid environments. From time immemorial, erosion in the catchments has been filling up these depressions with fine sediments resulting in the development of localized silty clay-loam and clay loam soil pockets, called 'Khadins', in the otherwise sandy and rocky territory.

14.2.10.2 The Khadins are usually flooded during monsoon and if necessary, a bund is laid down with a view to collecting the runoff from the catchments. These low lying areas are cultivated as and when, the water recedes and they become ploughable in rabi (winter) season. In a few instances of lighter and better drained soil pockets, and also in cases where smaller catchments with lesser run off, are involved, 'Khadins' are cultivated in the Kh arif (monsoon) season also.

14.2.11 AGRICULTURAL INNOVATIONS

14.2.11.1 The differential adoption of the recommended agricultural practices is a crucial problem facing the extension workers. Some of the factors like age of the farmer, size of land holding, social participation, caste status, educational status, technical know-how, value orientation etc. have been widely reported to have relationship with the

adoption of innovations. The technique of multiple correlation was used to find out the extent of variation in innovatives due to these factors in the region.

14.2.11.2 The inter-correlation matrix and percentage variation in adoption due to the independent variables indicated that the land holding score, irrigated land holding score, membership participation score, knowledge test and material possessions were significantly correlated with the adoption score. Membership participation and knowledge scores amounted for a greater amount of variation (53.23% and 51.51% respectively) as compared to land holding score (14-88%), irrigated land holding score (11.16%) and material possession (17.67%). There was also highly significant correlation between membership participation score and knowledge test which taken together accounted for a variation of 66.26%, that is, an additional variation of 13.03 per cent as compared to membership participation score alone. Irrigated land holding score and membership participation considered together accounted for an additional variation of only 2.15%, and material possession score and knowledge test accounted for an additional variation of 2.40%. When any other character was included with membership participation score and knowledge test score, there was no significant gain. The study thus suggest that it will be useful to encourage as much participation and involvement in various activities as possible and to explore the ways and means to provide full knowledge of the improved package of practices and the qualities of the innovation as these two factors pre-dispose the farmers to quicker adoption of innovations. It may also be useful to start extension activities with the people having comparatively greater participation in various activities and possessing more knowledge about the innovations rather than giving greater weightage to those possessing larger farms having greater material possessions, better value orientations and to those belonging to certain particular age group.

14.2.12 Animal-human relation

14.2.12.1 As mentioned in the case of the human population, the high mortality among the livestock also used to take away a substantial lot of the family herds. The arid zone society had, therefore, developed a tradition of considering it prestigious to possess a large number of livestock. Quantity over quality was preferred as the periodic high

morality used to bring forth a balance between the livestock population and the grazing resources. Like the growing human population the livestock population has increased from 10.27 million in 1961 to 16.44 million in 1972. The desertic areas possess some of the best breeds of cattle, sheep, goats, camels, etc. The pressure of livestock on the grazing lands, however, is a acute and there is a perpetual shortfall of forage requirements. The production from livestock is consequently low.

14.2.12.2 To have effective and balanced use of the ecosystem and for utilising different types of grasses, shrubs, tree leaves etc., the households used to have a mixture of animal types including cattle, camel, sheep and goats etc. Only in very rare cases the households resorted to raising only one species. Even in recent times, the average herd composition with a household in the Anupgarh-Pugal region has been recorded as follows : Malhotra et. al, 1968). In the course of interviews, many farmers had confined to us that keeping of different types of livestock provided them some security during the prevalence of certain diseases which affect some animal types and not the others. It needs to be mentioned here that the farmers in the arid zone did raise, and still raise, goats wh ich are branded by the foresters as the most potent destructors of ecosystem. The importance of goats, according to the farmers, lies not merely in the returns this hardly animal gives to its owner, but also in its role in th e raising of sheep. Goats often act as foster mothers to lambs as well as assist the shophered in grazing and herding the sheep. Also, in case of any attack by wild beasts it is only the goats which bleat and give an instant indication to the owner about the attack. The rate of mortality among sheep is comparatively higher than in goats during scarcity conditions. It is a common saying among the desert people that "oont chodde aakra aur bakri chodde kankra" i.e. during scarcity conditions, the camel will only leave the Calotropis while the goats will only leave pebbles. This implies that the goat can survive on the most scantly vegetation. The goat also acts as a poor man's cow.

14.2.12.3 The deeply ingrained socio-religious beliefs of the farmers in different spheres of life have often been found to over-ride prudence and the connected rituals often and to the already meagre resources available. The households belonging to the upper castes also consider it irreligious to get their bulls castrated and often wait till an opportunity for exchanging the same is available. Similarly, another ritual and belief regarding freeing a bull leads to deterioration of the quality of the local

cattle. The ceremony is known as Sand Ankna. In Rajasthan, the villages annually arrange a feast for dogs and other daieties with laddoos made of wheat flour ghee and sugar. Street dogs in Jodhpur and elsewhere are regularly fed by the kind hearted people. The pigeons, too, have their daily role of grain. Feeding ants is another usual feature of the society. Likewise, the rodent is an integral part of the social fabric. While most of the villagers deplore its damaging prospensities, many revere it for its hallowed association with Ganeshji. The famous "Rat Temple" of Deshnokh (near Bikaner) is an example of the admiration of the people for this crafty creature. Even though outright killing and immediate control of some of the harmful rodents may appear fully logical, it may be essential to adopt a balanced approach in this respect in view of the deeply ingrained beliefs and religious sentiments of the people.

14.2.13 Vegetation-Human Relationship

14.2.13.4 The ever-exploitation of ever dwindling vegetational resources started ever since the historical period, was accentuated during the times of Princely States and is on the verge of doom at present in the arid land of Rajasthan. Due to over-cultivation, the feed-back regeneration process of trees and shrubs is being hampered by the cultivator, for he maintains a bare minimum treeshrubs population in the crop field, and rest is uprooted, resulting in lowering the woody biomass production.

14.2.13.2 The tree and shrubs are indiscriminately cut not only from their own fields but from Government and other unoccupied lands for : (a) meeting the fuel requirement; (b) the top-feed of livestock; (c) thorn fencing; and (d) construction of thatched hutments.

14.2.13.3 The requirement and over-increasing demand is huge and over-exploitation of the vegetal resources is inescapable. The older people in the village admit that during the course of years the number of trees and shrubs has gone down steadily and not even 35-40 per cent of what was available 300 years ago has been left over. Additionally, a large proportion of population burns dung which would have otherwise been used for manure purposes. Thus the rapidly growing population has inflated the demand for wood for different purposes while it has reduced the area under fallows, waste and forests.

14.2.13.4 As it is cultivation of crops alone is a big gamble in the arid areas since the rainfall would not only vary five to ten folds from one year to another, but also during the same year at places just a few kms from each other. Most desert dwellers therefore, raised livestock as a subsidiary occupation and allowed shrubs and trees to grow alongwith cultivated crops to mainly over risk and uncertainty of crop maturity. In good rainfall years, however, added returns were thus accruable.

14.2.13.4 Brief details of agroforestry practices adopted by the desert dwellers in relation of Bordi and Khejri are provided below :

(i) Bordi is mostly taken with Bajra (the pearl millet) crop which is the stapple food of the population of arid areas. Right with the start of agricultural operations viz. "Sood" that is cleaning of the fields, Bordi plants are allowed to remain and are not taken out. Care is also taken that while plaughing and weeding, Bordi plants are not removed during rainy season. Bordi plants sprout each year from the root stock, which are left in the fields in the preceding year. The plants also, get established from the seeds which fall in the fields. Twenty to thirty years before an acre of field sown with Bajra contained about 100-120 plants of Bordi. However with the recent introduction of tractor majority of the Bordi plants get removed and the density per acre has reduced to only 25-30 Bordi plants in many cases. The farmers can ill afford not to use the tractor but wish that ways and means be explored for greater number of Bordi plants in Bajra fields. Most knowledgeable farmers admit about the reduced number of Bordi plants, its excellent feed, fencing and food values, and suggest for exploring ways to have more number of these trees. Research work pertaining to the sowing Bordi in lines in Bajra fields should be explored. Farmers look forward to science for telling them the practices to be adopted for such modifications including row to row and plant to plant distances etc. Bajra crop matures in October and is harvested while Pala harvesting is done generally in November-December, when the leaves are left for storage purpose. In scarcity periods Bordi is cut twice a year i.e. in April and May and in November-December. Bordi is also grown with Jowar crop in the same fashion as in case of Bajra. However, when taken in combination with legumes like moth, moong and gowar, the production of these legume crops gets reduced..

(ii) Khejri termed as a king tree in the arid Rajasthan grows well in combination with crops like Bajra, legumes (moth-moong) and oil seeds. The density of this tree traditionally preferred and maintained in one acre area under crops, was about 25 to 35 trees. The plants getting a vertically straight shape were allowed to grow while the deshaped ones were removed. As in case with Bordi the introduction of tractor for cultivation purposes has effected the density of these trees in the field boundaries while they would prefer to learn more if plaughing through tractor could also help them retain the number of trees traditionally present in the fields.

(iii) Khejri as is well known, provides livestock feed (leaves) vegetables (Sangariya) (fruits) (Khokha) and timber. When not lopped (as among one of the communities namely Bishniois) the leaves that fall on the ground and fertility to the soil. It may be pertinent to recommend here that those engaged in researches for amelioration of the desert dwellers may intensify effects for providing recommendations to the farmers regarding optimum number of Khejri trees that could be taken per unit are and to suggest the improvement in the package of practices being followed by the farmers for growth of these trees.

14.2.13.5 Awareness of the traditional agroforestry practices reveal the importance of developing greater knowledge on the past and present activities of the dwellers pertaining to agroforestry. This provides leads for developing new knowledge which could consequently bring about improvements in the package of traditional practices and provide suggestions for effective adjustments according to the changed and changing situational factors. Developing or improving upon the traditional shrubs and trees grown in combination with crops and search for alternatives assumes further significance, specifically in the change in the system of agricultural operations.

14.2.14 Desert spread and desertification

14.2.14.1 It has been further revealed that the conditions leading to accentuation of desertification within the desert areas are becoming more pronounced due to the reckless exploitation of land due mainly to substantial increase in the animal and human population in the desert. The ever increasing burden naturally has caused acute imbalance in resources use pattern leading to increasing desertification. Consequently

more and more marginal lands have come under plaugh. The current intense human land ratio, over exploitation of resources including use of marginal lands consequently led to lower soil fertility and productivity of crops as well as grasses in the region. Heavy infestation of insects, deterioration of land, crop diseases, erraticity of rainfall and keeping less fallow land were the most predominant reasons of decrease in yield. The study has identified the human factors for diagnosing the processes by which resources are being depleted.

14.2.14.2 The farmers opined that as a result of interplay of the increasingly harsh climatic factors and increase of population and in its needs, the region has been experiencing accentuation in conditions of desertification over the last 25-30 years and was also stated to be prone to the same effect in near future. The dwellers perceived and attributed the process to the prevalence of improper winds, lesser precipitation, greater erraticity and uneven distribution of rainfall, decreased natural vegetation, introduction of eric vegetation, impoverishment of soil, increasing salinity build up lower yields per unit area and increasing famine periods as compared to 25-30 years ago.

14.3 FUTURE THRUST IN HUMAN FACTOR STUDIES

14.3.1 Matching with the research resource personnel, the sociological studies undertaken at CAZRI so far formed mainly an adjuvant of the basic resources surveys and could place emphasis on the macro-cosmic studies through socio-economic surveys. Only a few problem oriented studies could be undertaken. The studies so far undertaken have no doubt provided significant information consistent with the objectives but at the same time have revealed the necessity for undertaking micro-cosmic and inductive studies to achieve the aim of bringing out the cosmic and inductive studies to achieve the aim of bringing out the positive and negative socio-cultural elements influencing development of the area. More specifically in following items may be suggested.

(i) Social anthropological studies on cultural factors impeding planned socio-economic changes, Anthrogeographical studies, rural social organisation, socio-cultural spill over in and around the border districts of arid zone, micro-cosmic studies of representative arid villages and cultural perspectives of human behaviours.

(ii) Studies on sedentarization of nomadic population which include the history of nomadism, groups of nomadic population and its role in economy of region, pattern of economic and social organisation and associated social and economic factors, migratory habits, routes of migration, role of socio-economic and political institution, their values, practice, beliefs, problems and measures for rehabilitation.

(iii) Environmental perception studies on nature of interaction between man, land and environment, nature and extent of symbiotic relationship between groups, spatical aspects of rural living, settlement types and social structure, history of land use and allocation, social aspects of desertification and measurement of social indicators of desertification.

(iv) Studies on scheduled castes, scheduled tribes and backward communities which include nature and extent of the level of their livelihood, socio-economic status, social mobility, social problems, formal and informal institutions and agencies and programmes which function to maintain the social and economic conditions of these parts of community.

(v) It was strongly advocated that the socio-economic investigations of similar type as conducted for arid zone of Rajasthan be conducted for arid zone of Gujarat and Haryana.

TABLE 1

SHOWING PRESENT LAND USE IN DIFFERENT ARID DISTRICTS

Sl. No.	District	Reporting area in km^2	Area in different land use categories as per cent of total reported area											Net area sown
			Not available for cultivation				Other uncultivable land excluding fallow land				Fallow land			
			Forest	land put to non-agril. use	Barren & unculturable land	Total	Permanent pasture and other grazing land	land under misc. tree crops	culturable waste	Total	Other fallow waste	Current fallow	Total	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							(Rajasthan 1977-78)							
1.	Barmer	28,170	0.50	2.13	4.86	6.99	7.70	-	13.06	20.77	12.14	6.99	19.13	52.61
2.	Bikaner	27,410	0.55	4.41	0.11	4.52	1.31	-	54.14	55.45	6.68	3.94	10.62	28.86
3.	Jaisalmer	38,310	1.57	0.99	8.98	9.97	2.27	-	79.87	82.15	0.60	0.36	0.97	5.34
4.	Jodhpur	22,560	0.09	3.99	6.34	10.33	4.92	-	1.06	5.98	22.21	10.37	32.58	51.02
5.	Nagaur	17,640	0.51	4.48	3.63	8.11	4.42	-	0.17	4.59	5.50	16.78	22.28	64.51
6.	Churu	16,860	0.30	4.21	0.06	4.27	2.85	-	2.67	5.52	7.59	7.30	14.88	75.03
7.	Jalore	10,560	1.52	3.31	8.14	11.46	4.83	-	0.66	5.49	11.17	11.46	22.63	58.90
8.	Jhunjhunu	5,930	5.73	3.04	2.70	5.73	7.59	-	0.87	8.43	2.36	4.89	7.25	72.86
9.	Sikar	7,750	1.55	3.10	7.61	10.71	6.19	-	1.81	8.00	4.65	11.48	16.13	63.61
10.	Pali	12,300	5.93	3.74	12.11	15.85	7.56	-	1.63	9.19	13.33	10.73	24.07	44.96
11.	Ganganagar	20,630	0.78	5.19	0.53	5.72	0.48	0.05	13.96	14.49	2.08	4.17	6.25	72.76

1. Bharara, L.P. 1978. Social Indicators of drought prediction in a village community of Rajasthan desert. Presented at International Symposium - Post Plenary Session - Anthropology and Desertification. CAZRI, Jodhpur, December 19-21.

2. Bharara, L.P. 1978. Socio-economic consequences of drought in an arid tract - a case study. Presented at International Symposium on Arid Zone Research and Development, CAZRI, Jodhpur, February 14-18.

3. Bose, A.B. Malhotra S.P. and Bharara, L.P. 1965. Socio-economic aspect of the practice of goat keeping in Central Lower Luni Basin. Indian Forester 91(5) 73-80.

4. CAZRI, Jodhpur (1964). Recent Development in Rajasthan Souvenir volume.

5. CAZRI, Jodhpur (1974). Summer Institute on Desert Ecosystem and its improvement.

6. CAZRI, Jodhpur (1978). Arid Zone Research in India. Silver Jubilee Volume.

7. Census of India (1973). Rajasthan series 18 - Part II A, Director of Census Operations, Rajasthan, Jaipur.

8. Malhotra, S.P. and Bose, A.B. 1963. Problems of rehabilitation among nonadic Banjaras. Ann. Arid Zone 2(1) 69-91.

9. Malhotra, S.P., Joshi, P.L. and Bharara, L.P. 1966. Impact of land, water and vegetation resources on the economy of the cattle breeders of a desert village. Ann. Arid Zone 5(2) 219-228.

10. Malhotra, S.P. 1966. Ritual and belief concerning animal control Indian Rodent Symposium, Calcutta.

11. Malhotra, S.P. and Bose, A.B. 1967a. Nyat as an agency of social control among the Banjaras. Leadership in India. J. Social Res.

12. Malhotra, S.P. Bharara, L.P. and Joshi, P.L. 1967 b. Role of Animal Husbandry in Anupgarh Pugal region. Indian Social Bull. 5(1) 11-20.

13. Malhotra, S.P. 1971. Nomads of Indian Arid Zone. 21st International Geographical Congress, Symposium on arid zones.

14. Malhotra, S.P. Joshi, P.L. and Rao, J.S. 1974. Relative importance of some socio-economic factors in the adoption of agricultural innovation. Indian J. Ext. Education 10(1:2) 62-64.

15. Malhotra, S.P. S.P. 1976. Opinion survey and desertification. Proc. on development and conservation of desert and semi-desert lands, Ashkabad, USSR.

16. Malhotra, S.P. (1977). Socio-demographic factors and nomadism in the arid zone. Desertification and its control. pp. 310-323.

17. Malhotra, S.P. (1977). Tradition perceptabilities of environment and desertification - A case study. Economic Geology, Clark University, Massachussett.

18. Malhotra, S.P. and Mann, H.S. (1978). The Human factors and desertification in the arid zone of Rajasthan. Proceedings of the Symposium entitled "Anthropology and Desertification" Jodhpur.

19. Malhotra, S.P. Rao, J.S. Goyal, D. and Patwa, F.C. (1972). Population land use and livestock composition in India and its arid zone. Ann. Arid Zone II (1:2) 116-21.

20. Mann, H.S., Malhotra, S.P. and Kalla, J.C. (1974). Desert Spread - A quantitative analysis in the Arid Zone of Rajasthan. Ann. Arid Zone 13(2) : 103-1

21. Mann, H.S. (1971), Operational Research Project on Arid Land Management - An Interim Report. UNU workshop on Training and Management and Management for Arid Lands.

22. Mann, H.S., Malhotra, S.P. and Shankaranarayan, K.A. (1977). Land and resources utilisation in the arid zone Desertification and its control, pp. 89-101.

CHAPTER XV

15.0 TRANSFER OF TECHNOLOGY IN THE ARID ZONE

15.1 INTRODUCTION

15.1.1 It is now fully realised that transfer of technology is highly location specific. Practices found suitable in one region may not hold good in the other. Even within the regions one particular technique may not be applicable on two locations - though identical in soil climatic characteristics. To quote an example, Hyderabad and Sholapur are situated on seminar latitude and longitude with seemingly identical Agro-climatic, ecological and adaphic features. Yet, the rainfed cropping systems found suitable for the two locations are entirely different and so is their agricultural potential (Virmani, 1979). The reason for this was traced in the location **specificity of soil moisture environment**. There may be several such factors operating in different situations

15.1.2 Location specificity of problems is at its peak in the Arid Zone. Quite a few of these do not exist else where in the country. Hence, the scope for horizontal transfer of technology to the Arid Zone is limited to the aspects like introduction of improved plant types.

15.2 CONTRIBUTIONS OF CAZRI

15.2.1 Establishment of the Desert Afforestation Research Station at Jodhpur in 1952, its expansion as the Desert Afforestation and Soil Conservation Station in 1957, and its further reorganization, expansion and redesignation as the Central Arid Zone Research Institute in 1959 are adequate indications of the Government's response to the call for initiating, expanding and intensifying research and investigation on arid zone problems.

15.2.2 At the CAZRI, research and investigations are being conducted by a team of over 100 scientists, with the collaboration of over 150 technical staff on interdisciplinary projects. Investigations being undertaken pertain to the disciplines of Agricultural Economics, Agronomy, Agrostology, Animal Physiology and Nutrition, Animal Production, Cartography, Climatology, Genetics, Geology, Geomorphology, Hydrology, Microbiology, Organic Chemistry, Pedology and Soil Chemistry, Physics (Wind and Solar Energy), Plant Ecology, Plant Physiology, Production

Economics, Ranage Management, Silviculture, Sociology, Soil Conservation & Agricultural Engineering, Soil Physics, and Toxicology and Plant Protection.

15.2.3 Participation and coordinated involvement of biological, physical and social scientists in problem oriented research is a unique feature of the functioning of the CAZRI - which was envisaged and emphasised for the establishment of this Institute.

15.2.4 Apart from CAZRI, CSWRI (Avikanagar) and State Agriculture Department, several other research and survey organizations have since long been contributing to the information base for the development of this region. Some of the important ones among those are : Central (UNDP Sponsored) and State Ground Water Boards, Defence Laboratory (Jodhpur), Geological Survey of India. University of Jodhpur, Department of Forests, State Public Health and Engineering Department and even ONGC. Work on few aspects like use of saline water, has also been carried out at the University of Udaipur, particularly in late sixties. By and large, these efforts have been successful, and a knowledge based on the desert region has been built up.

15.2.5 The CAZRI right since its establishment in 1959 besides its own survey and research activities for the development of management technology, took upon itself to synthesising the information available with various departments, by arranging numerous seminars, symposia and conferences. These have been particularly made use of in the resource survey functions of the Institute.

15.2.6 Even before the institute had its Extension Wing, the techniques for afforestation (on sandy, rocky and semi-rocky habitats), roadside and shelterbelt plantation, sand dune stabilisation and range management, were well demonstrated on as many as 80 locations of government and community lands. Besides research and demonstration values, those projects have since served as excellent feed-back mechanism to effect further refinements in the technology.

15.2.7 Transfer of proven research findings to the users was not included in the character of functions of CAZRI when it was established in 1959. Later, in 1967, the first Achievement Audit Committee in its review

of the Institute's work recommended that sufficient technological know-how for efficient conservation and utilization of resources has since been developed and it is time to implementing it for ameliorating the desertic conditions and increasing the overall productivity of the region.

15.2.8 The committee thus proposed for including a section of Extension in the existing Division of human factor studies.

15.2.9 During this period beginning middle sixties a limited programme on technology transfer with respect to improved seeds, use of fertilizer and improved crop management practices on rainfed and irrigated lands was initiated under the National Demonstrations Programme of the country. This, however, made only a limited impact for want of a sound back up mechanism of adaptive trials at operational level, (Anon, 1970). Transfer of technology with respect to dry farming was further geared up in 1971 with the establishment of a Dry Farming Research Main Centre at CAZRI, under the National Coordinated Project for Dry Land Agriculture. A blue print for action was drafted in collaboration with State Agriculture Department, as envisaged in the programme, for simultaneous research and application of results on farmers fields at pilot scale (Anon, 1972). The pilot project was in operation upto 1979. Considerable impact of the programme was observed as revealed by education studies carried out by the State of Rajasthan and the ICAR (Rastogi and Annamalai, 1981).

15.2.10 Consequent upon the recommendation of the second Achievement Audit Committee in 1973, a Division of Extension and Training was established at the CAZRI in 1973-74. A programme of systematic transfer of technology was drawn up and implemented.

15.2.11 The approach consisted of the following components :

(i) Operational research

(ii) Diffusion of knowledge through mass communication

(a) Farmers fairs at the Institute and sub-stations.

(b) Village level farmers training programme/field days.

(c) Exhibition during various socio-cultural f
in rural areas and on scientific - cultura ions
at regional, state and national levels.

(d) Radio talks, Film shows, press notes in local papers.

(e) Distribution of leaflets in local languages on improved technology.

(iii) Field demonstrations on improved package of practices for crop production, tree plantation, rainfed orchard (Ber) development and guidance/training on health care aspects of livestock.

(iv) Training of extension personnel (District and Regional level).

15.2.12 Operational Research was initiated in collaboration with District Rural Development Agency in 1973-1974. The project is located 25 km away from Jodhpur on Jodhpur-Nagaur Road covering a cluster of 5 villages - Daijar, Manaklao, Basni Karwad, Basni Lachha and Palri. Important components of the technology are sand dune stabilization, plantation of trees (wind breaks, shelter belts), grass land development, dry farming, arid horticulture (introduction of ber growing), efficient utilisation of limited water resources (Sprinkler and Drip Irrigation), plant protection including rodent pest control and animal husbandry (sheep and goat). This programme aims at not only the demonstration of the improved technology, but also helps pin-pointing the socio-economic and technological constraints in its diffusion and adoption by the users (Anon, 1980).

15.2.13 To couple the social aspects of rural transformation effectively with the technological aspects of the operational problems in the transfer of technology, the programmes are being executed from the social organisational and technical angles concurrently. An interdisciplinary team consisting of scientists from the Institute, officers of various state government departments, local bodies and also the farmers of the area is engaged in the programme to adopt an integrated approach to the use of available human, soil, water, plant, animal and solar-energy resources. While executing the programmes, the principle of 'social audit' is given due place so that the weaker section of the society derives the maximum benefit and all the components of the package are successfully demonstrated (Annon, 1980). The results have been convincing both with respect to diffusion of knowledge and development of a feed-back mechanism for incorporating desired refinement in the technology by way of further experimentation (Anon, 1979).

15.2.14 Under the ICAR's Golden Jubilee Commemoration programme "Lab to Land Project", 200 farm families (marginal and small) were adopted by the Institute for demonstration of proven techniques and technologies particularly to dry farming, introduction of ber orchards, efficient utilisation of limited irrigation resources and animal husbandry aspects. The programme was started in 1979 in selected watershed areas - Palrinath, Agolai and Rampura (Jodhpur), Kanawas (Pali), Gajner and Naurangdeshar (Bikaner) and Deva and Balad (Jaisalmer), in collaboration with respective District Rural Development Agencies. The programme has since made a good impact and more and more people are coming forward to join the activities.

15.3 ONGOING DEVELOPMENTAL PROGRAMMES IN THE ARID ZONE

15.3.1 The IRD programme in the Arid Rajasthan has three sub-programmes for arresting the desertic conditions and increasing the overall productivity of the region.

(i) Watershed development and management in DPAP areas (Directorate of Soil Conservation, Jodhpur).

(ii) Desert afforestation (Directorate of Desert Afforestation and Pasture Development).

(iii) Pasture Development (DPAP).

15.3.2 Whereas the ongoing soil conservation programme of the state was modified to fit into the watershed approach in 1971-72, the DPAP (Pasture Development) and Desert Afforestation Programmes were started in 1974-75 and 1978, respectively, by the State Government. Among other things, the basis for the establishment of later two organisations at field level was the realisation that sufficient knowledge base on desert grasses and forestry aspects has been built up by institutions like CAZRI.

15.3.3 The above three programmes are coordinated by District Rural Development Agencies in each District. In 1975 Desert Development Commission was established with Headquarters at Jodhpur, to coordinate all such development activities at regional level. The CAZRI has since been providing (at least partly) the scientific back up, to the grass land development and afforestation programme in the desert region.

15.3.4 Similar coordination can also be developed for the arid areas of Gujarat and Haryana States.

15.4 RECOMMENDATIONS FOR STRENGTHENING OF TRANSFER OF TECHNOLOGY MECHANISM IN THE ARID ZONE

(i) Operational Research :

The CAZRI has one Operational Research Project located near Jodhpur. This is not enough. The Institute may initiate at least three more projects near its regional centres (Pali, Bikaner and Jaisalmer) to provide scientific back up to watershed management, afforestation and sand dune stabilisation and khadin cultivation development programmes run by the State Government.

(ii) Multi-disciplinary Research Centres

Even within the Arid Zone, soil-climatic variations are considerable. There is a need, thereafter, to establish Multi-disciplinary Research/Adaptive trial centres at all such locations. The character of functions of these centres will comprise :

(a) Testing of available technology to incorporate desirable modifications/alterations based on location specificity of problems

(b) Adaptive field trials on farmers fields.

(c) Field demonstration of perfected technology.

(d) Mass mobilisation and saturation of the area with the improved package by adopting suitable extension/communication techniques.

Agricultural Universities (Haryana, Gujarat and Udaipur) may establish these centres in consultation with CAZRI.

(iii) Lab to Land Programme :

The watershed development approach should be the basis for the efficient implementation of this development activity. All the people inhabiting a particular watershed need to be involved in the programme though the maximum benefits should be given to weaker sections. In

large areas of the Arid Zone watershed boundaries do not exist. In such cases, this programme may be implemented on a 'village' or a 'group of villages' basis depending upon extension manpower and financial resources.

(iv) Organizational infrastructure :

There is a need to create well linked infrastructure at State/ Regional Panchayat Samiti and village levels with suitable combination of administrative, development and research personnel, for planning, coordination and implementation of extension programme. It may also be necessary to consider to sufficiently strengthen the institution of the Desert Development Commissioner, Rajasthan so that this institution can take up the desert development programme on more concerted basis. Creation of such institutions for development of desert areas of Gujarat and Haryana may also prove quite fruitful.

(v) Training :

CAZRI's training programme for district level Extension Officers (State Government) and subject matter specialists (Universities) need to be strengthened. Areas for such trainings may be identified from locational Research Development feed back systems. A Coordinating Committee consisting of CAZRI scientists, State Development and research officers and university authorities should be formed to draw out syllabi and calendar of courses for such trainings.

(vi) Recommendations :

State Development authorities, Universities of the region, CAZRI and other institutes should constitute a committee under the Chairmanship of the Chief Minister to review cooperation and coordination. State Development Department will be the Secretariat. There should be another committee under the Chairmanship of Director, CAZRI with experts from various organisations to continuously review and adjust the methods of cooperation and division of labour.

R_E_F_E_R_E_N_C_E_S

Anonymous, Annual Report, CAZRI, Jodhpur, 1970.

Anonymous, Blue Print for Action, Dry Farming Research and Development Project, CAZRI, Jodhpur, 1972.

Anonymous, Report of Extension Research and Training, Division of Extension & Training, Quinquennial Review of CAZRI, 1980.

Anonymous, Report of National Committee on Backward Area DPAP, Chapter 16, strategy for Transfer of Technology, 16.21 and 16.36, 1981.

Rastogi, B.K and Annamalai, V. "A study on the adoption and diffusion of recommended technology in dry land areas", Report of Agro-Economic research in drought prone areas coordinating cell, RICRP for dry land agriculture, Hyderabad, August, 1981.

Virmani, S.M. "Climatic approach to transfer of farming systems technology in the Semi-Arid Tropics" Proceedings of the International Symposium at ICRISAT, India, on Development and Transfer of Technology for Rainfed Agriculture and SAT farmer, pp : 93-101, 1979.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
						Haryana (1979-80)								
1.	Hissar	809	3	0.37	134	16.56	148	18.23	3	0.40	3	0.40	204	25.15
2.	Sirsa	514	1	0.11	24	4.68	112	31.70	3	0.60	2	0.30	165	32.19
3.	Bhiwani	710	4	0.60	255	35.09	44	6.10	2	0.29	3	0.48	280	39.03
						Gujarat (1975-76)								
1.	Kachchh	592	66	11.10	129	21.69	11	1.82			98	16.53	Nag.	
2.	Jamnagar	615	113	18.04	133	21.59	26	4.29			2	0.34	Nag.	

* Note besides above, Cotton in Ganganagar, Hissar and Sirsa districts and Groundnut in Ganganagar district are important.

MINUTES OF THE FIRST MEETING OF THE WORKING GROUP ON ARID ZONE RESEARCH HELD IN THE DST ON 29TH NOVEMBER, 1980

Present

1.	Shri B. Sivaraman	Chairman
2.	Shri H.S. Mann, CAZRI	
3.	Dr. P.S. Pant, IMD	
4.	Shri D.P. Dhoundial, GSI	
5.	Shri Subrata Sinha, GSI	
6.	Dr. R.V. Rama Rao, Andhra University	
7.	Dr. N.L. Ramanathan, Depearmtne of Environment	
8.	Dr. R.I. Sarkar, IMD	
9.	Dr. M.N. Qureshy, DST	
10.	Shri R.P. Dhir, CAZRI	
11.	Dr. D.K. Biswas, Deptt. of Environment	
12.	Dr. D.K. Rakshit, DST	Member-Secretary

Prof. P.D. Bhavsar could not attend the meeting.

Background note prepared by the Secretariat regarding the constitution of the Working Group and a technical note prepared by IMD on the problems of meteorology with reference to atmospheric phenomena taking place in and around arid zone were circulated at the meeting.

The Chairman in his introductory remarks stated that in order to alleviate the various difficulties of our arid zone areas we need to understand first the basic problems associated with arid zones e.g. availability of natural resources and their optimum utilisation, land pattern and land use, socio-economic conditions of the people, and extension of desert etc. He also mentioned that in spite of a number of measures having been adopted to develop these areas, there had been a lot of deficiency due to the lack of our proper knowledge to deal with arid zone problems. He cited a few examples like the existence of brackish water at different places, toxicity to flora and fauna, identification of particular specimen of flora that can withstand the toxicity and the overall information on the availability and use of water in arid zone. On the question of water management in this area he mentioned about the issues like the effect of dust cover that may be the main reason of aridity, soil conservation, change in environment due to infiltration of dust and sand into the atmosphere etc. He also referred to the problems of animal husbandry, live-stock in arid zone area which is the primary economic force of this region. As regards applied research he invited opinion from the members about the application of our already acquired knowledge towards development of this area and what more is needed. In this context, he mentioned that Israel has done lot of work on hot arid zone and it will be useful to have some information on the work in Israel. As regards, cold arid zone, Canada and Russia may have done good work; and it will be useful if we can get some information from these countries also.

While mentioning about the task of the present committee he stated that under the term of reference this committee has been assigned the responsibility to look into the aspect of Arid Zone research in wider perspective and to suggest both short and long term approaches as regards R&D programmes that would be of national interest.

Dr. Rakshit conveyed the views of Secretary, DST that this Working Group may look into the total aspect of arid problem and suggest viable programmes of research to be taken up in future. He also mentioned that, though this Committee was set up as a follow-up of the of the recommendations of Indo-US Sub-Commission meeting held in February 1980, it was the opinion of Secretary, DST, that the group need not at present limit its consideration to Indo-US cooperative programme only. Programmes requiring some sort of assistance from US side may automatically emerge out of the deliberations of this Working Group. After a brief discussion on the Terms of Reference, the Chairman requested all participants to offer their opinion about problems in general and suggest future work of the Committee to perform its assigned task.

Dr. Mann mentioned that as a follow-up of UNEP Conference on Desertification held at Nairobi in 1977 a programme of trans-national monitoring of desert phenomena has been launched by the Central Arid Zone Research Institute. In addition, this institute has also taken up an operational research project in parts of Rajasthan which is in different stages of implementation. At the instance of the Chairman, Dr. Mann agreed that CAZRI would prepare a status paper on research work taken up by them so far on arid zone problems. Shri D.K. Biswas referred to the country report prepared by India for UNEP Conference on Desertification, a copy of which he had distributed to members.

Dr. Rama Rao mentioned about the potentiality of landsat imagery in monitoring desertification. In this context, he stated that after studying the repetitive landsat imagery of some of the areas in semi-arid track, particularly over Ramanathpuram, there was some evidence of this region becoming arid, therefore, stressed on the need for monitoring the processes taking place over semi-arid regions. A point was raised about the ground truth of Landsat imagery and it was understood that ISRO has done some work in this area.

Shri Dhoundial stressed the need for developing a multi-institutional collaborative project proposal to study the arid zone problems in the country with primary objective to develop the area. He mentioned that for the purpose of monitoring and understanding the global trend in desertification there may be a necessity for some collaboration with outside agencies. Shri Sinha explained about the utility of the aerial photos in preparing base maps and land use pattern maps which GSI has already prepared in respect of Rajasthan. He also mentioned that GSI by making repetitive survey with the help of aerial photos has been monitoring the critical dunes land use pattern over parts of Rajasthan; and it has been found that misuse of land in arid zone does sometime even affect the land out side the zone. He also mentioned that contrary to the impression, sand dunes development or movement is a very slow change and not easily discernible on a definite time frame.

Dr. P.S. Pant described the work of IMD as regards collection of meteorological data including rainfall from arid zone areas. While presenting the report prepared by IMD he mentioned that though from the variability of the rainfall we can demarcate some areas which are perpetually deficient in rainfall, the real issue would be about the correct definition of aridity as the total annual rainfall is concentrated in few months of the year. However, after identifying our goals it could be possible to look into the aspect of observational set up required to be maintained in this area for collection of meteorological data. Dr. Sarkar informed the group that IMD has already done agro-climatic zoning of Rajasthan area on the basis of surface water availability. On a query from members it was clarified that this agro-climatic zoning would need modification taking into account the availability of ground water potential.

After a detailed discussion it was agreed that the following documents on the subject will be made available to DST by respective members/organisations for circulation to other members for their advance study so that these could be discussed thoroughly at the next meeting.

(1) Report on Physical, Biological effects on Aridity.

- Action by Dr. Mann

(2) Status paper on R&D work so far carried out on Arid Zone problems in the country.

- Action by Dr. Mann in consultation with member rep. GSI.

(3) Report on digital processing technique of Landsat imagery with reference to the study of arid zone phenomena.

- Action by Dr. Rama Rao

(4) Report about correction of ground truths with respect of Landsat imagery.

- Action by Prof. P.D. Bhavasar

(5) Status of basic research in the areas related to crop, animal husbandry, soil characteristics, water use etc. in arid zone area and gap, if any.

- Action by Dr. Mann/CAZRI

(6) Note on Environmental Disturbances created by Rajasthan canal.

- Action by Dr. N.L. Ramanathan/CAZRI

(7) Note on salinity problems of arid zone areas.

- Action by DST (Dr. J.S.P. Yadav, Central Soil Salinity Research Institute, Karnal, to be approached).

(8) Status of problems in cold arid zone in India.

- Action by DST (Ministry of Defence to be approached)

(9) Status of arid zone research of other countries.

Action by DST (Embassy of USA, Australia to be approached)

(10) Report on Soil and Water studies in arid zone and aridity/ salinity monographs.

- Action by DST (FAO to be approached)

MINUTES OF THE 2ND MEETING OF THE WORKING GROUP ON ARID ZONE RESEARCH HELD IN THE DST ON 29-30 MAY, 1981

Present

1. Shri B. Sivaraman, Plg. Commission — Chairman
2. Shri H.S. Mann, CAZRI
3. Shri R.P. Dhir, CAZRI
4. Shri K.A. Shankararayan, CAZRI
5. Shri G.M. Banerjea, GSI, Jaipur
6. Shri S. Ray, GSI, Jaipur
7. Shri D.C. Dassarma, GSI, Jaipur
8. Shri S. Banerji, IHP
9. Shri S.K. Das, IMD
10. Shri S.C. Sharma, IMD
11. Dr. R.V. Rama Rao, Andhra University
12. Shri M.N. Banerjee, Planning Commission
13. Dr. D.K. Rakshit, DST — Member-Secretary

The following agenda papers were circulated to members.

(i) A note on the problems of Soil Alkali and Salinity in arid and semi-arid areas with particular reference to the work done at the Central Soil Salinity Research Institute, Karnal (Haryana) - Prepared by Dr. JSP Yadav, Director, CSSRI, Karnal.

(ii) Desert Development - A review of recommendations of Symposia and Seminars - prepared by Shri Gian Chand, CAZRI, Jodhpur.

(iii) Arid Zone Research in India - prepared by CAZRI, Jodhpur.

(iv) Status note on GST's work on Arid Zone-prepared by GSI.

(v) Collection and correction of ground truths with respect to Landsat Imagery - prepared by Space Application Centre, Ahmedabad.

(vi) Research and project activities - a brief report prepared by Dr. R.V. Rama Rao, Andhra University.

The subject of discussion was split into the main aspects of arid zone viz. (1) Salinity, Hydrology and Meteorology aspects and (2) Problems relating to Animal Husbandry, Soil Characteristics, Water Use, etc. - related to arid zone development. The meeting continued for two days on 29 and 30 May 1981.

2.0 The Chairman in his introductory remarks stated that with the increased application of science and technological methods it should be possible to reverse the on-going processes of ecological deterioration by adjusting water and land use for human needs in Arid Zone areas. While referring to the use of environment for the development of arid zone he mentioned that ICAR could have contributed some inputs to this committee for perusal. As ICAR did not furnish any input he requested CAZRI to furnish whatever information they possess on this important issue so that proper recommendations can be made. It was agreed that CAZRI with if possible necessary inputs from ICAR prepare a paper on land, water and environmental use for the development of arid zone in the country. (Action by CAZRI).

The Chairman then reviewed the work already done by the group and felt that there still exist gap of information particularly on the nature of land, water (both surface and ground) in Arid Zone areas. After a detailed discussion it was decided that working papers would be prepared on the following topics for consideration at the next meeting.

(i) Land status in Arid Zone - by CAZRI/GSI.

(ii) Hydrological problems - Availability and quality of water - GSI/CGWB.

(iii) Meteorological problems - Rainfall pattern related to agriculture - IMD.

The Chairman invited a general discussion on a few specific problems like (a) Reason for aridity in Rajasthan keeping the clouds away, (b) the reported salinity in both surface and ground water, and (c) management of salinity - their present status and what more has to be done. After a discussion it was felt that it would be worthwhile if some organisation undertakes a project of monitoring what has been happening after Rajasthan canal was dug as such study may give the essential clue for understanding some of the basic problems and subsequent taking up relevant development programmes for the region.

The Chairman made a reference to one of the recommendations of National Agricultural Commission about drawing water from the neighbouring areas for the development of arid zone. He also mentioned about the importance of adaptive research that could be effectively done by the State Agricultural Organisations. He then requested Dr. Yadav to present his paper on the problems of soil alkali and salinity in arid and semi-arid areas.

Dr. Yadav while mentioning about the present status of soil characteristic in semi-arid and arid regions of the country totalling about 7 m. hectare, stated that almost half of this area is saline and the remaining alkaline. On the question of reclamation and management of saline areas he stated that Punjab and Haryana Governments have already decided to reclaim the affected land in phased manner on yearly basis for which purpose the respective State Government provides some subsidy as incentive. As regards reclaiming the land in Rajasthan and Gujarat he mentioned that the ground water available in this area are at sufficient depth and of poor quality. Dr. Mann mentioned that

resource survey have been conducted over at least 1/3rd of arid zone for which data of land, terrain, physical and chemical properties of soil are available. He also mentioned that CAZRI has been conducting survey in phased manner, of the salinity and alkaline content of all land in arid zone. It was opined that large storage of ground water might be the primary cause of salinity mainly in the near by irrigated area and as such pumping out of ground water may reduce the salinity to some extent. From the above observations it was felt that the continuous monitoring of conditions in this area may be desirable so that suitable drainage to cut capillary action from the salinity below, could be designed. It was decided to recommend a plan of action to be undertaken by CSSRI Karnal/ CAZRI/Agricultural universities.

Shri Banerjea of GSI mentioned that geomorpholcgical map is very essential for various development programme in Arid Zone area and in this context he mentioned that a small scale map of Rajasthan has already been prepared. After discussion the committee decided to recommend that GSI should prepare a detailed geomorphological map of Arid Zone and also prepare a resource map of scale 1:50,000.

As regards the problem of non-availability of sufficient water in this area it was felt necessary to undertake study for maximum utilisation of rain water. The meeting discussed about the location of research stations to deal with problems of arid/semi arid zone and it was generally viewed that research stations should be located in their respective zones. It was decided that CGWB and GSI jointly prepare a paper on hydrological problems of arid zone area.

Action by : GSI/CGWB

The Committee also identified some of the important problems like (a) development of saline soil area through cultivation of flora and faunna (b) introduction of new cultivator (c) bio-saline development programmes (d) animal husbandry and animal feed in Kutch area (e) breeding of more saline resistive varieties etc. It was decided that both CAZRI and Karnal would jointly prepare a basic paper on salinity aspect of Arid Zone in the context of above development programme.

Action by : CSSRI/CAZRI

Shri Banerji of IHP while referring to water availability in Arid Zone area mentioned that both modern and traditional methods are being pursued in Rajasthan area for water conservation. In this regard he mentioned that efficient water harvesting technology should be adopted to feed cattle and other livestock. As regards water transportation he mentioned that open cannal system should be discouraged due to high evaporation losses. More study should be conducted for using saling brackish water in this region. As regards exploitation of water in hard rock area he mentioned that the information of geological faults/fissures should be increasingly used. After a discussion it was decided that for arresting salinity of water, meteorological, geological and hydrological aspects of the region should be thoroughly examined. Detailed mapping of ground water should be done early to avoid over exploitation and also to replenish ground water.

The hydrological aspects of some of the areas like Jaisalmer and Ghaggar where water is scarce, were discussed. It was also decided

that some programmes should be identified to trace the flow of underground water for their efficient conservation and harvesting with relation of land use planning.

The problems of studying rain water run off, their routing and the associated parameters were also discussed for efficient water management. It was felt necessary that water balance of large water shed areas should be studied. The existing methods of water harvesting and water conservation in different terrains, were discussed. It was felt that a study for conservation and harvesting of surface water for arid zone development can be undertaken by CAZRI and accordingly CAZRI was requested to submit a paper highlighting what more they can contribute.

Action by : CAZRI

The meeting discussed sedimentation, evaporation, siltation problems in which CAZRI was understood to have done a lot of work. CAZRI was requested to prepare a paper indicating their present status of work and what more should be done to fill up the gap, if any.

Action by : CAZRI

The nature of saline water in different zones, the need for their mapping for understanding the nature of intrusion of saline water was discussed. It was felt that permissible limit for human and animal use, should first be well defined and arrangement made to desaline the water to the extent essential in order to establish correct Cost-Benefit from desalination programmes. As regards desalination, the availability of solar Kiln developed by Bhavnagar as a small scale plant for village system was considered. It was felt that CAZRI could collect more detailed information on desalination plant and prepare a report for this Committee.

Action by : CAZRI

Shri S.K. Das, IMD briefly presented the board division of the region according to nature and severity of drought and also according to crop pattern. He also informed the members about the present network of evaporameter and soil moisture measurement stations in the arid regions of the country. Dr. Dhir mentioned that CAZRI has done lot of work on climatology in desert area and they have set up few stations on their own. After discussion it was decided that both IMD and CAZRI should jointly consider the present network of evapo-transpirometer and soil moisture measuring station and suggest optimum programme for intensification of the network as necessary.

Action by : IMD/CAZRI

Prof. Bhavsar while presenting his note on collection and correction of ground truths with respect to landsat imagery stated that a comprehensive technical report on ground truth data collection has been prepared by ISRO, a copy of which was circulated to members. He mentioned that information on the type of rock, soil or crops in a small sample area can be easily derived from satellite photographs. As regards capability of satellites, he mentioned that SEO (Bhaskara) launched by India has a resolution of 1 km, landsat imagery has a resolution of 80 m and the future satellite to be launched by India during 1984-85 will have a resolution of 80 m. If the need is well identified ISRO can

undertake the work. It was decided that Dr. Shankar Narayan and Prof. Bhavsar will jointly consider the potential of satellite imagery towards programme related to arid zone development and find out the specific need.

Action by : CAZRI/ISRO

Problems related to Crop, animal husbandry, soil characteristics, water use etc. in arid zone area were discussed. The Chairman stressed on the importance of surveying the whole of arid and semi-arid region quickly with the help of landsat/aircraft imageries. For this purpose he invited suggestions whether CAZRI and GSI could undertake the work in association with State Government of Rajasthan. In regard he mentioned that there may be a necessity for taking up a block level plan of action. On a reference from Dr. Mann that CAZRI's present work is limited to arid zone only, Chairman stated that CAZRI's responsibility should also cover semi-arid area and for this he wanted to know whether CAZRI has the adequate capacity to undertake the work. Shri Banerjea mentioned that the increase in aridity is primarily due to human interference and therefore we should give more emphasis on land use planning. After a detailed discussion it was agreed that more emphasis should be given on water balance study, drought probability, climatic changes and rainfall pattern of arid and semi-arid area. For this study the primary responsibility should be with IMD and the study should be a part of integrated resource survey. However in the field of agro-climatology and systems analysis, work should primarily be done by CAZRI in association with IMD.

The movement and stabilisation of sand dune was discussed. was suggested that GSI should continue monitoring the location and movement of sand dunes. As this would require detailed ground survey it was decided that both CAZRI and GSI would bring out a paper indicating the plan of work.

Action by : GSI/CAZRI

The problem associated with identification of right type of plant, flora and fauna, germ plasm etc. resistive to arid zone condition were discussed. In this context, the work of regional centres of our agricultural universities which were meant for supporting the work of CAZRI was discussed. It was intimated that these regional centres were supposed to play multi disciplinary role involving scientists from all fields. After discussion it was decided that CAZRI would prepare a paper highlighting the role of regional centres and their present status for detailed consideration of the Committee.

Action by : CAZRI

Chairman intimated that CAZRI has a division of extension as a part of education but it is not working satisfactorily. It was felt that greater involvement of the division of extension would be beneficial.

The meeting discussed on th e Resource inventing, technology utilisation and transfer of technology etc. in the context of control of pests and diseases to crops. It was decided that CAZRI will prepare a paper on the above aspects for consideration at the next meeting.

Action by : CAZRI

The meeting ended with a vote of thanks to the Chair.

ANNEXURE III

MINUTES OF THE THIRD MEETING OF THE WORKING GROUP ON ARID ZONE RESEARCH HELD IN THE DST ON 25-26 AUGUST 1981

Present :

1. Shri B. Sivaramah, Ex-Member, Planning Commission — Chairman
2. Dr. H.S. Mann, Director, CAZRI, Jodhpur.
3. Dr. A.S. Ramanathan, Dy. Director, General, IMD, New Delhi.
4. Dr. R.V. Rama Rao, Head, Geo Engg. Division, Andhra University.
5. Dr. D.K. Biswas, Deptt. of Environment
6. Dr. M.N. Qureshi, Director, DST.
7. Dr. K.A. Shankaranarayan, CAZRI.
8. Dr. R.P. Dhir, CAZRI, Jodhpur.
9. Dr. D.K. Rakshit, DST. — Convener

Prof. R.D. Bhavsar, SAC and representative of GSI could not attend the meeting.

The following documents were circulated to members.

DOC. No. 1

1. Background Note on the need for development of Location Specific Technologies for improved use of Salt Affected soils and saline ground waters in Arid Zone.
2. Outline of recommendations for development of surface and ground-water resources in Arid Zone.
3. Network of Evapotranspirometer and soil moisture measuring stations-future plan of work.
4. Problems of evaporation and sedimentation in Arid Zone
5. Specific Remotely sensed data requirements of CAZRI ISRO's 1984-85 satellite launching.
6. Work conducted by Central Arid Zone Research Institute.
7. Information on desalination plant.
8. Copy of letter dated 12 August 1981 form Embassy of the United States of America, New Delhi addressed to Dr. Rakshit, Principal Scientific Officer, DST, New Delhi.

0.1 The Chairman in his introductory remarks expressed his desire to finalise the report of the Working Group by October-November 1981. Accordingly, he requested members to extend their maximum cooperation to complete the task in time. He also stated that he would like to hold the next meeting of the W.G. at CAZRI, Jodhpur on 7th & 8th Sept. 1981 where the problems related to transfer of technology could also be discussed with the representatives of the concerned state governments. He informed the members that he had already written to the Chief Secretaries of the State Governments of Rajasthan, Gujarat and Haryana to depute their repreentatives/experts to the meeting at Jodhpur on 8th September, 1981.

0.2 It was decided that Dr. Rakshit would stay on at Jodhpur after the meeting on 8th and with the help of concerned scientists of CAZRI would prpare the draft report for consideration at the next meeting proposed to be held at Delhi from 22-23 September, 1981.

0.3 Thereafter members discussed on the documents prepared by CAZRI, and the salient points emerged and decisions taken at the meeting were as under :

1.0 Document No. 1

Background note on the need for development of location specific technologies for improved use of salt affected soils and saline ground waters in Arid Zone :

1.1 It was decided that the document would be revised by C.S.S.R.I. taking into the following additional points.

i) Regionalisation of Saline area, identification or parameters to be looked into and also institutes to be responsible for doing the work.

ii) basic understanding of the management of salt affected soil-their mapping and field application.

iii) effect of irrigation on Arid Zone and introduction of water in this area and the problems created.

iv) pests and diseases, human health aspect of Arid Zone, arising out of irrigation.

v) Problem of Sheep and cattle development in Arid Zone, that may arise because of irrigation, like pests and diseases.

vi) Screening of germplasm of trees grass and cultivated crops etc.

vii) Hydrology and Mapping of underground water and effect of saline water on normal soil and good water on saline soil in Arid Zone-Identification of agencies who are concerned with this.

Document No. 2

Outline of recommendations for development of surface and groundwater resources in Arid Zone.

2.1 It was decided that CAZRI will rewrite the document taking into consideration the following additional points.

i) As regards integrated drainage system w.r.t., Luni river system the same w.r.t. Sahibi and Rann System may be included.

ii) In the Hard Pan situation the behaviour of recharge ground water.

iii) Inclusion of fossil water, its identification.

iv) Recharge w.r.t. River Ghaggar and problems encountered, study of the flow of ground water linked with Ghagger based on tracer technique-CAZRI to discuss with BARC and TIFR to find out who could undertake this work and also outlines of work to be undertaken.

v) Mapping of flood water, quantity and movement, identification of availability, contour of sub surface water, identification of institutions to undertake the work.

Document No. 3 :

Network of Evapotranspirometer and soil moisture measuring stations-future plan of work.

3.1 It was decided that this document would be expanded with the inclusion of description and statement of instruments/stations being operated in Arid Zone by CAZRI, IMD and also about the basis of water balance study of demarcating Zones depending on soil, rain and crop production. It may also include information on the optimum need for water balance study related to crop production. It was suggested that CAZRI would update the document and IMD would supply their inputs to CAZRI for inclusion in the document.

Action by : CAZRI/IMD

Document No. 4 :

Problems of evaporation and sedimentation in Arid Zone.

4.1 The problems associated with the control of evaporation loss of stored water from open ponds etc. were discussed. The Committee felt that there is scope for R&D work to reduce the evaporation loss. Introduction of surface film or storage of water in sub surface layer could be tried on experimental basis. As regards the study conducted by CAZRI on suspended sediment regions in the Luni and its tributaries it was suggested that some study should be made to hold back sediments by applying the method of soil conservation. It was realised that the that the problem suggested under sedimentation relates more to management of sedimentation. After discussion it was decided that materials under the document would be included in the chapter of water management.

Document No. 5 :

Specific Remotely sensed data requirements of CAZRI vis-vis ISRO's 1984-85 satellite launching.

5.1 The group considered the specific needs of CAZRI as listed in the document. As regards the requirement of satellite imageries with greater discriminability it was suggested that the requirement should be more specific. It was understood that DST has already sanctioned a project for Resource evaluation to IIT, Kharagpur and Andhra University.

It was decided that relevant points of this project may be reflected in the present document. For this purpose, Dr. Rama Rao was requested to contribute the necessary inputs to CAZRI.

Action by : Dr. Rama Rao

5.2 The capability of landsat imagery and future ISRO satellite in land use mapping were discussed. It was decided that full information or what aspects are available from landsat imageries and what parameters and sensors to be included in ISRO's future satellites are required to be identified and reflected in the document. It was realised that satellite information will be very useful for land use mapping and monitoring the change in course of time. It was decided that this document will be further refined by CAZRI in consultation with ISRO and materials included in 'land use' chapter.

Action by : CAZRI/ISRO

Document No. 6 :

Works conducted by Central Arid Zone Research Institute, Jodhpur.

6.1 There was no significant comment on this document. Dr. Rakshit informed the members that Secretary, Department of Environment has recently brought to the notice of Secretary, DST the recommendation of Indian National MAB Committee about the need for ecological development of Rajasthan Desert with special reference to arresting the advancement of Sand dunes. After discussion it was agreed that CAZRI will include in this document aspects related to the above subject. Department of Environment would be requested to give relevant inputs to CAZRI.

Action by : DoEnv./CAZRI

Document No. 7 : Information on desalination plant

7.1 After a discussion on this document, it was decided that CAZRI will expand/modify the document taking into account the following additional points.

(i) Availability of solar energy and wind energy in Arid Zone.

(ii) Harnessing of solar energy in the form of solar distillation plant etc., R&D requirement and identification of institution/groups.

(iii) Wind energy utilization for drinking water pumping etc., R&D need and identification of institutions/groups.

Document No. 8 :

Copy of letter dated 12 August 1981 from Embassy of the United States of America, New Delhi.

7.2 Dr. Rakshit briefly presented the proposal received from US side to organise a joint Indo-US workshop on Arid Zone problems. In this context he stated that this was one of the recommendations made by the Indo-US Joint Sub-Commission on S&T at its meeting held in February 1980. Members felt that as there are certain gaps in our knowledge in various processes taking place over Arid Zone areas, the full understanding of

which is required for development of this area. It was decided to recommend holding the workshop particularly for the purpose of exchange of scientific knowledge and information and also identify a few selected research programmes in which collaboration would be advantageous.

8.0 The meeting ended with a vote of thanks to the Chair.

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MINUTES OF THE 4TH MEETING OF THE WORKING GROUP ON ARID ZONE RESEARCH HELD AT CAZRI, JODHPUR ON 7-8 SEPT., 1981

Present

1. Shri B. Sivraman, Ex-Member Planning Commission. — Chairman
2. Dr. H.S. Mann, Director, CAZRI, Jodhpur
3. Shri G. Appa Rao, IMD, Pune.
4. Dr. D.K. Rakshit, DST, New Delhi — Convener

Also Present

5. Dr. Ishwar Prakash, CAZRI, Jodhpur.
6. Dr. Harcharan Das, CAZRI, Jodhpur.
7. Dr. R.N. Shrivastava, G.S.I., Jaipur.
8. Dr. H.S. Dauley, CAZRI, Jodhpur.
9. Dr. G.S. Shekhwat, Deptt. of Agriculture Jaipur.
10. Dr. J.K. Basu, GSI, Jaipur.
11. Dr. H.P. Singh, GSI, Jodhpur.
12. Dr. S.P. Malhotra, - do -
13. Dr. M.K. Ghosh, - do -
14. Dr. B.V. Ramana Rao - do -
15. Dr. J.P. Gupta - do -
16. Dr. A.N. Lahiri - do -
17. Dr. Bimal Ghosh - do -
18. Shri Gian Chand - do -

Prof. P.D. Bhavsar and Prof. Rama Rao did not attend the meeting.

The following documents were circulated to members/participants.

1.1 Agronomic Research - Prepared by CAZRI.

1.2 Horticulture Research - Prepared by CAZRI.

1.3 Forestry Research - Prepared by CAZRI

1.4 Animal Husbandry Research - Prepared by CAZRI.

1.5 Pasture Development Research - Prepared by CAZRI.

1.6 Plant Protection Research - Prepared by CAZRI.

1.7 Sociology and Agricultural Research

II.1 Outline of recommendations for development of surface and ground water resources in Arid Zone.

Appendix I - Investigational Needs of the Rajasthan Canal Command Area.

Appendix II - Artificial Recharge.

Appendix III - A note on structure and functioning of Nadi System.

Appendix IV - Notes on "Khandin" system.

II.2 Agroclimatic approach for crop development.

II.3 Outline of an Approach for Delineation of Cropping Zones in Rajasthan based on Moisture Availability Index.

II.4 Solar energy, wind power and biogas.

III. Working paper on fields/problems on which IRD can contribute (prepared by IMD).

IV. Ecological Improvement in Arid Lands (Prepared by DOEn).

The Chairman in his introductory remarks while appreciating CAZRI for bringing out the relevant base papers within a limited time period stated that in some of the documents information pertaining to similar areas in Gujarat and Haryana were not included. He requested the concerned authors to collect as much as possible the relevant information from these states and include these in concerned chapters of the report. Thereafter all the papers were taken up for discussion and the decision taken on each paper are mentioned below :

Doc. i.i - Agronomic Research

The Chairman enquired whether on the basis of work done so far CAZRI can give a direction for high yield production, both cropwise and regionwise. After a discussion, it was decided that the paper would be re-written taking into account the following additional points :

i) Agro-meteorological situation in relation to rainfall pattern and its spatial distribution - regionalisation of crop varieties indicating best cropping period.

ii) Detail objective what should be done for each crop breeding programme - present status of work and future need.

iii) A paragraph on the mixed and inter-cropping - advantages and limitations.

iv) Contingency planning to meet any unfavourable situation.

v) Specific condition under which grain yield decreased substantially in 1979 and 1980 (vide table 7).

Doc. 1.2 - Horticultural Research

It was felt that there are other varieties of orchards over and above reported in the document particularly locally used pads, fruits for humans and fodder for animals. Such varieties of traditional household usage should be developed by selection first and breeding next. It was decided that the documents would be rewritten taking into account the following additional points :

i) Objective to be stated precisely.

ii) Write up for all other varieties including their present status and what to be done for improvement.

iii) Identification, selection and economics of different varieties.

iv) Statement of work by Udaipur University.

Doc. 1.3 - Forestry Research

It was decided to revise the paper taking into account the following additional points.:

i) Transplantation technology - its possibility and efficiency to accommodate more trees.

ii) Linking the research aspect of insects, pests and disease with FRI.

iii) Future research need in relation to sand dune stabilisation.

Doc. 1.4 - Animal Husbandry Research

This was discussed in greater detail and it was decided to revise the document taking into account the following additional points :

i) Reaction of breeds (goat, sheep and cow) to varying circumstances.

ii) Assignment of priority to each variety taking into consideration constraints of fodder availability.

iii) Hey storage - ratio of mixing with green fodder for maximum efficiency - Need for basic work to be done by Universities of sheep, goat and cattle, also NDRI stations.

iv) Traditional practice.

v) Breeding practice - selection of breed with reference to arid zone.

vi) More details about selection procedure.

vii) Importance of goat to be highlighted in more details - its present status and methods to improve the present condition.

viii) Identification of agency/bodies who will undertake further study - Universities to be involved.

ix) Inputs from Udaipur University.

Doc. 1.5 - Pasture Development Research

The paper was discussed in great details. It was stated that there is a wide variety of rodent species (20 Nos.) in this region and their population was reported maximum in the world. It was also reported that one of the varieties - Bandicota - is highly susceptible to plague and its number is increasing in Arid Zone with the change of crops. It was felt necessary to undertake intensive study on some of the aspects like (i) Environmental factors associated with sudden increase in rodent population, (ii) balance between various species and their dependence on different feeds (iii) any biological conflicts in keeping the balance and

(iv) integrated pest control etc. It was felt necessary that Universities should take up this part of study on priority basis.

It was decided that the paper would be revised taking the above aspects into consideration suggesting a definite frame work on protection aspect of the manace.

Doc. 1.7 - Sociology and Agricultural Economics

The paper was discussed and it was decided that sociology part will be separated out and included as a separate chapter in the document. As regards agricultural economics it was decided that a separate para on economics aspect will be included in respective chapters.

II.1 Outline of Recommendations for development of surface and ground water resources in arid zone.

The paper was discussed in greater details. It was decided that it will be revised taking into account the following additional points :

i) Write up on drainage required for flushing out saline area and also the undefined drainage.

ii) Water-balance study required for understanding surface, sub-surface drainage etc.

iii) Desalinisation of Water - A reference to Bhavnagar work will be included.

iv) Additional recommendation for maximum utilization of water.

v) Inclusion of Narmada system for advance research needs.

II.2 Agroclimatic approach for crop development

The paper was discussed in details. It was noted that IMD also has done some work in this area and accordingly it was felt appropriate if CAZRI and IMD jointly take up the studies. It was decided that the paper would be revised taking into account the following additional points :

i) As regards future observational network, a few centres would be identified in Haryana and Gujarat. The work to be done by these centres should be spelt out clearly.

ii) For doing work jointly by CAZRI and IMD, the link between the two organisations would be spelt out.

iii) A paragraph on crop weather model developed by IMD for rain fed and other areas to be given including its likely future extension as applicable for arid zone.

iv) IMD's paper on 'Fields/problems on which IMD can contribute to be included as Appendix.

II.3 Outline of an approach for delineation of cropping zones in Rajasthan based on moisture availability index.

There was no comment on this paper. It was decided that the relevant materials may be included in Agro-climatic Chapter.

II.4 Solar energy, wind power and bio-gas

There was no comment, it was decided that there will be a sep rate chapter entitled "Alternative source of energy utilisation in Ar Zone" incorporating therein the objectives and other institutes to be associated.

It was decided that all the papers discussed at this and earlier meetings will be re-written as chapters keeping the above stated points in view and would be sent to DST (Dr. Rakshit) within a week i.e. by 15th September 1981 for preparing the draft report of the Working Group.

It was agreed that the following chapters will be re-written/ finalised by experts as indicated against each chapter;

Chapter	Title	To be prepared by
I.	Physiographic setting a) Climate b) Aridity c) Soil and Landform d) Geology e) Surface and groundwater conditions f) Natural vegetation g) Present landuse h) Livestock	Dr. R.P. Dhir
II.	Agronomic Research	Dr. H.C. Daulay and Dr. A.N. Lahiri
III.	Horticultural Research	Dr. H.C. Das
IV.	Forestry	Dr. H.C. Das
V.	Animal Husbandry	Dr. P.K. Ghosh
VI.	Pasture Development	Dr. H.C. Das
VII.	Plant Protection	Dr. I. Prakash and Dr. H.C. Das
VIII.	Salinity and use of saline water in Agriculture	Dr. R.P. Dhir
IX.	Surface and groundwaters (with appendix Water Balance)	Dr. Shankaranarayan
X.	Alternative source of energy utilisation	Dr. J.P. Gupta and Dr. Ishwar Prakash
XI.	Agroclimatic aspect (dust aspect, lysimeter etc. crop development).	Dr. Rama Rao and Dr. Appa Rao
XII.	Sand dune movement	Dr. B. Ghose and Dr. A.K. Sen

XIII.	Environmental monitoring	Dr. Shankarayayan
XIV.	Sociology and Human factor	Dr. S.P. Malhotra
XV.	Transfer of Technology	Dr. Malhotra and Dr. H.P. Singh
XVI.	Space Sensing Application	

* Dr. Malhotra will give write up on Agricultural Economics relevant to different sale-areas for inclusion in respective chapters.

III. Transfer of Technology

This aspect of arid zone development was discussed on 8th September, 1981 with senior level representatives (both Administration and Technical) of the concerned states. Earlier, the Chairman addressed a letter to the Chief Secretaries of Rajasthan, Gujarat and Haryana. In addition to the members of the W.G. and other concerned experts of CAZRI the following State Government Officials attended the meeting :

1. Shri A.C. Shah, Secretary,
   Agriculture, Forest, Co-operation,
   Govt. of Gujarat.

2. Shri K.P. Karamchandani, Chief Conservator
   of Forest, Government of Gujarat.

3. Shri B.H. Jhala, Jt. Director of Agriculture
   Govt. of Gujarat.

4. Shri R.S. Kumat, Secretary, SSO,
   Govt. of Rajasthan.

5. Shri Vijay Verma, Commissioner,
   Desert Development Programme,
   Govt. of Rajasthan.

6. Shri P.C. Singhi, Dy. Secretary (DDP)
   Govt. of Rajasthan.

7. Shri Mohan Lal Mathur, Addl.D.Ag.
   (Soil Conservation), Govt. of Rajasthan.

8. C.M. Chadda, Chief Engineer,
   Ground Water Department, Govt. of Rajasthan.

9. Shri G.S. Shekhawat, Senior Agronomist,
   Agrl. Deptt., Govt. of Rajasthan.

10. Shri S.P. Mehta, Project Director (Hydro),
    SSO, Jaipur.

11. Shri H. Dikshit, T.A. (II) and Sr. Hydro-geologist,
    Ground Water Board, Govt. of Rajasthan.

Representatives of the State Government of Haryana did not attend the meeting.

Two report - one prepared as a part of the report of National Commission on Backward Area Development and the other prepared by CAZRI on transfer of technology - were circulated to the participants.

The Chairman while giving the background of convening this meeting stated that in view of the importance of developing the arid zone area through increased application of science and technology, the department of science and technology, Government of India, had some time back constituted a Working Group in Arid Zone Research with the purpose of preparing a status report as regards R&D work and identifying gaps of further research in this area. In this context, he stated that as research in this field is intimately related to development of the area, there is a need to look into various administration and technical aspects for smooth and efficient transfer of technology to the users. He cited the various stages and difficulties in transfering the technology to the village. Accordingly he felt that it will be essential if community participation is ensured while planning for the transfer of technology. In this connection he referred to the general guidelines on this aspect recommended by the National Commission on Agriculture and suggested that this should be refined depending on the local needs.

As the goal of research on arid zone problems is for the welfare of the whole community, he stated that the technology to be developed and suggested should be basically location specific. In this connection, he suggested that we should give more stress on adaptive research in which respective Extension departments, State Agricultural Universities should also take active part besides central institutions like CAZRI, GSI and IMD.

The meeting discussed on the role of CAZRI demonstration centre, training of State Government personnel, role of F&V programme, financial and implementation aspect of various technologies suggested.

The representatives of Rajasthan stated that while a large number of schemes for arid zone development were under their consideration and adequate fund allocated but a large portion of this fund could not be utilised due various administrative problems. The Chairman stated that for smooth implementation of development programmes and consequent utilisation of fund it would be better if it is made available at the project level.

The representative of State Government of Gujarat stated that though CAZRI is a central institution to lookafter the problems of arid zone areas in the whole, there has been no impact of CAZRI's effort in the development programme of Gujarat. They also stated that for watershed development programme common people are not generally involved and it is the soil conservation people, who are responsible for watershed management project. It was stated that the work of forestry development in watershed areas is generally handicapped due to lack of community involvement. While supporting the idea of people's participation in implementing the programme, it was felt that management of village forest at the initial stage should be with the Government for smooth operation and people's participation can be effected after the initial stage.

After a detailed discussions on various problems associated with transfer of technology the following salient points emerged :

i) It was realised that technology to be suggested for arid zone development should be in conformity with the needs of individual localities. Technology developed for some region/locality may not be suited for another locality as it is dependent on terrain characteristics and people's attitude.

ii) Agro-meteorological information should be used extensively for understanding the soil moisture potential and other factors before suggesting the technology.

iii) Mere transfer of technology of seeds and plants may not be of much help to the farmers. The transfer should be in the form of package deal which include aspects related to Animal Husbandry, Forestry, Cropping pattern etc. The existing practice of farmers, their difficulties, specific needs should be taken into account before suggesting a new technology.

iv) CAZRI should open regional multi-disciplinary research centres - one at Gujarat, one at Haryana and two more at Rajasthan for rendering scientific back up for effective use of land and water for comprehensive purposes including animal husbandry, forestry; horticulture and fisheries.

v) Operational research should be taken up by Government Technical Departments with direct involvement of the concerned Universities. However, adaptive research should be introduced mainly at the State Technical Level.

vi) Technical Universities should be encouraged to undertake need based research with technical assistance from CAZRI.

vii) There should be at least one National Operational Research-cum-Demonstration Centre for each of the State of Rajasthan, Gujarat and Haryana. Number of sub-demonstration centres may be set up depending on the needs. This will enable rendering adequate back up for all watershed management project.

viii) There should be a regular programme of training of State Government personnel in CAZRI on different aspects of transfer of technology.

ix) There should be intimate linkage between State Department of Agriculture, preparations with CAZRI for easy exchange of information and technical data.

x) Community participation and involvement of universities in transfer of technology should be ensured at all states.

xi) Under the DPAP programme there should be at least one base farm per district.

xii) CAZRI should be associated in all rural development programmes of the states of Rajasthan, Gujarat and Haryana for expert assistance.

xiii) Financial autonomy should be given at the project level to remove any bottleneck in utilising the allocated fund effectively.

xiv) Problems of arid zone should be included in educational curricula of the respective states for larger awareness.

xv) There should be annual get together between State Government personnel and the scientists of CAZRI for exchange and dissemination of information related to arid zone development.

2.8.2.3 Intercropping of bajra with moth : Different intercropping systems tried with moth during 1979 and 1980 revealed that among pure cropping systems, moth in paired rows gave the maximum yield. Among the intercropping systems, planting one row of bajra in between the paired rows of moth gave the highest total productivity.

2.8.2.4 Planting systems : Of late, some interest has generated among dryland research workers in trying out the efficiency of newer systems of planting like the paired row system against the conventional (uniform) planting system. The experience gained at Jodhpur and with various crops has shown that the paired row system of planting is not inferior to the conventional system (Table 5).

Table 5 : EFFECT OF SYSTEMS OF PLANTING ON THE YIELD OF DRYLAND CROPS

Planting Systems	Grain yield of bajra (q/ha)		Grain yield of Mung (q/ha)	
	1975	1976	1975	1976
1. Uniform rows	38.1 (45 cm)	22.0	12.0 (30 cm)	7.4
2. Paired rows of bajra	40.3 (30/60 cm)	25.3	12.2 (20/40 cm)	8.1
3. CD (0.05)	MS	NS	NS	NS

2.9 JUDICIOUS FERTILISER USE

2.9.1 Fertiliser use on drylands has almost been non-existent, mainly owing to uncertain rainfall and the cultivation of non-responsive crop varieties. As such, the earlier belief of the dryland farmers that fertilizer application was injurious to dryland crops was justified. With the availability of fertilizer response varieties of dryland crops and the knowledge gained on the quantity, time and method of nutrient application; a judicious fertilizer use can offer enormous possibilities of increasing dryland crop production under normal and above normal rainfall situations and stabilizing them in years of subnormal rainfall.

2.9.2 A. Bajara : Based on the mean of two years (1971 and 1972) it was observed that bajra HB 3 did not respond to the application of nitrogen beyond 40 kg/ha. Results of a long term study are given in Table 6. A long term experiment on fertility management of bajra-bajra and

bajra-moong sequences carried out for six years revealed that maximum response is at 20 kg N/ha. Application of 20 to 40 t FYM/ha in alternate years and 10 t/ha every year brought out considerable organic matter build up over a 5 years periods. Organic manure treatments resulted in significantly higher grain yield of bajra over the application of inorganic nitrogen (Table 6). In bajra-mung rotation application of phosphorus to mung crop has been found to have considerable residual effect leading to higher grain yield of bajra growth in rotation next year. It was also found that a saving of 20 kg N/ha can be achieved by adopting bajra-mung rotation instead of continuous bajra every year.

Table 6 : GRAIN YIELD (q/ha) OF BAJRA AS INFLUENCED BY DIFFERENT FERTILITY

Fertility levels	1975	1976	1977	1978	1979	Mean
	(520)	(549)	(326)	(298)	(638)	
Control	2042	6.6	10.3	4.8	2.5	8.3
20 kg N/ha, inorganic every year	29.4	12.2	15.9	7.7	4.5	13.9
40 kg N/ha, inorganic every year	30.1	16.7	19.3	9.0	5.0	16.0
40 kg N/ha, inorganic once in two years	30.2	8.9	20.1	6.0	5.4	14.1
10 t FYM + 10 kg N/ha every year	23.8	16.5	19.1	10.8	6.8	15.4
20 t FYM once in two years	26.1	13.0	17.8	10.1	8.4	15.1
40 t FYM once in two years	27.0	17.8	25.0	10.8	8.6	17.8

Note : Figures in paranthesis indicate rainfall in mm during the years.

2.9.3 Oil seeds : A progressive increase in the yield of sunflower was recorded with the corresponding increase in the level of N. Response per kg of nitrogen was of the order of 9.0, 7.5 and 7.4 kg grain for 30, 60 and 90 kg N/ha, respectively. Irrespective of quantum and distribution of rainfall, seed yield of sesame increased with the increase in nitrogen level upto 60 kg N/ha. The response of phosphorus both in sunflower and sesame was not found to be economical.

2.10 CONTRIBUTION OF EACH OF THE IMPROVED PACKAGES IN MAXIMISING THE YIELD OF DRYLAND CROPS - BAJRA

2.10.1 Information gained from number of experiments on different components responsible for maximising the grain yield of bajra were put together with a view to assessing the contribution of each of the components to the increased grain yield of bajra. Five treatments were formulated indicating additive effective and were tried over fairly large sized plots. Yield are presented in Table 7.

Table 7 : GRAIN YIELD OF BAJRA (BJ 104) AS INFLUENCED BY DIFFERENT TREATMENTS

Treatments	Grain Yield (q/ha)	% Increase
1. Bajra local (RSK)	6.8	-
2. Bajra BJ 104 (uniform row)	12.8	88.2
3. Bajra BJ 104 (paired row)	14.4	12.5
4. Bajra BJ 104 fertilised 40 kg N/ha	19.0	18.1
5. Bajra BJ 104 fertilised + weed control	18.9	11.2

2.10.2 The use of improved bajra hybrid BJ 104 contributed to 85 per cent increased grain yield of bajra, followed by fertiliser use (18 per cent) weed control and paired row systems of planting each contributing about 11-12 per cent.

2.11 WATER HARVESTING AND RECYCLING

2.11.1 Based on studies carried out at Jodhpur, it was found that of the total seasonal rainfall, about 15 to 28 per cent could be harvested as run-off, the per cent rainfall days causing run-off being 45 to 62 per cent. The harvested rain water could be stored and recycled for a 'life saving' or supplemental irrigation. One supplemental irrigation (5-8 cm) given 27 days after seeding/transplanting of pearl millet in the IRRWH (Inter Row Water Harvesting) system, resulted in 13.2 and 37.3 per cent higher grain yield of direct seeded and transplanted pearl millet over the unirrigated pearl millet crop, respectively. In drought years, the beneficial effects of supple-

mental irrigation were more spectacular, resulting in 337 per cent higher grain yield over unirrigated pearl millet (2.2 q/ha). In good rainfall years and with an extended rainy season, the harvested rain water could be used for pre-sowing irrigation, thus enabling the double crop system of pearl millet - mustard, to be followed on drylands.

2.12 CONTINGENCY PLANNING FOR METTING ABERRANT WEATHER SITUATIONS

A. Late onset of monsoon or failure of normal sown crops due to early drought

i) Transplanting of bajra : Late sowing of bajra after third week of July is not desirable. Transplanting of 20-25 days old bajra seedling under such condition is recommended. Yield range 8-12 q/ha.

ii) Planting of legumes and oilseeds

Mung	:	2-9	25th July to 5th August
Cowpeas	:	K-11	
Moth	:	T-18	
Guar	:	2470/12	
Castor	:	Aruna	5th August onwards
Sunflower	:	EC 68414	

iii) Moisture conservation by removal of weeds and sowing of raya T-59 on stored moisture in rabi with the occurrence of rains in September.

B. Occurrence of drought late in the seasons (August onwards)

i) Recycling of run-off collected in pond.

ii) Thinning of crops stand to 50 per cent for use as fodder-bajra, mung, moth, guar.

iii) Intercrop fodder bajra in grain regumes, mung moth and cow-pea - harvest the fodder if the drought extends more than a week.

iv) Intercrop fodder legumes in castor - harvest the fodder if the drought extends more than a week or so.

2.13 PACKAGE OF PRACTICES FOR DRYLAND CROPS

2.13.1 Based on the information gained from a decade of dry farming research at CAZRI, Jodhpur, package of practices for major dryland crops of the regions have been formulated and given in Appendix 1.

2.14 OPTIMISATION OF LIMITED IRRIGATION WATERS

2.14.1 Through extensive irrigation : Extensive irrigation concept seeks to apply a small quantity of water over a large area rather than a large quantity over a small area. For example, when 82.5, 50 and 25 cm of water was applied, respectively, over 1 ha each of water, sunflower and mustard, the respective production was 5,458, 1,607 and 1,102 kg. The corresponding production from the same quantities of water applied over 3.2 and 1.5 ha of these crops was 9, 104, 2,712 and 1,935 kg. Use of water in the latter way will, therefore, decrease the return per unit of land, but will increase it per unit of water.

2.14.2 Through use of modern systems of irrigation chock basins are conventionally used for irrigation purposes in the area. On sandy soils with uneven surface, this method is very inefficient. Sprinkler irrigation of wheat crops has resulted in a yield of 4,301 kg/ha. This yield is about 33 and 27 per cent higher than from the conventional check basin and the border strip method of irrigation, respectively.

2.14.2.1 Some times high wind speed limit the use of sprinkler. Drip irrigation is not affected by winds. The system of drip irrigation enables the best use of every drop of the available water. This system resulted in a saving of 50 per cent of water (in potato crop) required under conventional furrow irrigation, and displayed a high potential for the use of saline water, which is widely prevalent in the area.

2.14.2.2 As the yields under drip irrigation have been far in excess of what at one time was through possible by conventional irrigation, the former method may be considered as in "instant transfer technology", more suited to high value, widely spaced vegetable crops. In the first stage, the utility of the technology is being demonstrated through an operational research programme undertaken on village level.

The only factor seems to limit its large scale adoption is its high high cost (Rs.18,500/ha) and maintenance problems. Economics has yet to be studied. Recent studies of stand geometry, simulated to minimum installation cost and water use by drip irrigation, have shown that double row planting resulting from 25 cm square or equilateral plant geometry reduces installation cost and water use by 50 per cent.

2.14.3 Maximisation of crop productivity through proper cropping patterns and water allocation

2.14.3.1 From the yield water relationship, in wheat the concepts of the optimum yield per unit of land when land is the limiting factor, the optimum yield per unit of water when water supply is limiting and the "lowest acceptable" yield concept for assuring the greatest number of farmers to benefit from available water supply have been developed.

2.14.3.2 An optimal irrigation programme to attain the maximum yield of wheat variety 'Kalyansona' with the least number and depth of irrigation has been worked out. In the optimized programme, the dates and depth of seasonal irrigations have been defined, and alternative irrigation plans to suit different water supplies have been formulated. To illustrate three selected plans applicable to adequate (1 Max), medium (1 med) and low (1 low) water availability situations are given in Table 8.

Table 8 : OPTIMAL (YIELD MAXIMISING) PLAN OF IRRIGATION (1) FOR 'KALYANSONA' WHEAT FOR THREE LEVELS OF SEASONAL IRRIGATION

Total seasonal irrigation (cm)	Irrigation (cm) on days after							Yield from irrg.	Total Yield (kg/ha)
	21	40	54	68	78	90	100		
8.4.1(I max)	7.2	10.4	11.8	13.2	14.0	14.9	12.6	4,234	5,430
40.0 (I med)	-	2.5	10.0	5.0	10.0	12.5	-	3,528	4,724
20.0 (I low)	-	2.5	-	5.0	7.5	5.0	-	2,472	3,668

2.14.3.3 Given a definite level of water supply, how farmers should allocate areas under different crops so as to maximise their gross returns? In the current context of severe restrictions on fertiliser availability, it is also of interest to know, in terms of farm plans, what impact this has on the farmer's gross returns? From a comprehensive research initiated since 1971, a procedure for a planning allocations of four content-rate water supplies (available from tube wells of 2, 4, 10 and 50 thousand gallons/hr pumping capacities) to four important crop alternatives viz., wheat, mustard, sunflower and safflower has been developed. The results showed that the area irrigated should be proportional to the available water supplies, wheat, mustard and safflower occupy, respectively 38, 31 and 31 per cent of the area irrigated, from whatever may be the available water supply. After assigning 56 cm water, 150 kg/ha N, and 125 kg/ha seed to wheat; 17 cm water, 30 kg/ha N, and 40 cm row spacing to mustard; and a preplant irrigation 50 kg/ha N. and 40 cm row spacing to safflower, this optimal plan showed the largest profit potential and the employment prospects. Sunflower was found uneconomical. An 80 per cent water deficit later in the season, or 50 per cent less fertilizer availability, does not materially alter the plan or the acreage, but to cope with the scarcity, the plan suggests transfer of 37 per cent of the total wheat area from the optimum to sub-optimum (29 cm) level of irrigation and withdrawal of fertilizer from safflower. However, if water deficit expectations shift to the earlier part of the growing season, it would pay to transfer water from wheat to mustard, but as soon as 100 cm of seasonal water is used, wheat crop would have to be assigned priority.

2.15 GAPS IN KNOWLEDGE AND FUTURE LINES OF RESEARCH

2.15.1 Much valuable work has been done to stabilize and increase crop production on rainfed lands of arid zones. However, there are many gaps in present day knowledge pertaining to rainfed agriculture. Some of them are given below.

i) Breeding crop varieties for different agro-climatic situation met in arid regions. Advantage should be taken of the world germplasm particularly in respect of pulses.

ii) Compatible crops for inter cropping/mixed cropping systems have been worked out however, precise information is still lacking in respect of suitable plant types and optimal plant population/proportion of each of the components and their management in relation to nutritional parameters.

Though appreciable work has been done on crop production under limited water supply conditions, still there is need to strengthen this work in respect of different soil, ground water quality besides identification of more efficient crops for utilising the limited irrigation water.

Considerable information is available on **run-off collection** and its utilizations but there is need to intensify research with regard to suitable material for farm ponds, checking of evaporation of the collected run-off an run-off recycling technology particularly with respect to suitable crop and their critical stages.

Tillage in relation to soil and nutrient conservation and crop stand establishment.

Problem of soil crusting and its control.

Studies on agro-forestry and silvi-pastoral systems for sustained production under marginal agro-climatic condition of arid regions.

Studies on integrated soil fertility and pest/disease management under dryland agriculture.

Assessment of contribution of individual component inputs for increased crop production with a view to identifying the most critical and low cost inputs for maximising crop production on drylands.

A P P E N D I X - I

Improved Package of Practices for major dryland crops

Crops

Bajra

Seed bed preparation	-	Use sweep cultivator
Seedling and seeding machinery	-	Use seed drill having fluted roller matering device
Sowing time	-	Sow in the end of the June or in the 1st fortnight of July
Efficient and high yielding varieties	-	BJ 104
Plant population	-	1.75 lakh plants/ha for direct seed and 2.5 lakh for transplanted crops
Planting system	-	Adopt paired rows system (30/60) cm of planting
Integrated nutrient supply	-	For integrated nutrient supply follow mung-bajra rotation and save 20 kg/ha of fertiliser nitrogen
Fertilizer use	-	Apply 40 kg N/ha in two splits (1/2 place at sowing and 1/2 top dress 3-4 weeks after sowing
Technology for transplanted	-	Transplant 20-25 days old 2.5 lakh seedlings/ha and apply 40 N + 40 P kg/ha

Kharif pulses/grain legumes

Mung, moth and gaur

Efficient short duration and high yielding varieties	-	Mung(S-8, S-9), moth (Jadia T-18) and guar (Durgapura saffed, 2470/12, FS 277)
Sowing time	-	2nd half of July
Seed rate/plant population	-	Use 12-15 kg/ha seed to maintain 3-5 lakh plants/ha
Intercropping system	-	Plant one row of bajra in the inter spaces of legumes sown in paired rows (20/40 cm) for increased productivity
Fertiliser use	-	Apply 40 kg P_2O_5/ha or as per the soil test
Weed control	-	Incorporate Treflan @ 1 kg a.i. per ha before sowing and one hand weeding 20-25 days after sowing

3. Oil seeds

Til

High yielding variety	-	Type T-13
Plant time/plant population	-	Sow @ kg/ha in end of June or first fortnight of July and maintain plant population of 2.5 lakh/ha
Fertiliser use	-	Place a mixture of 20 N 30 kg/ha at sowing and top dress 20-30 kg N/ha 3-4 weeks of seeding on receipt of rain
Planting system	-	Adopt paired rows system 20/40 or 30/50 cm and intercrop one row of guar

4. Castor

High yielding varieties	-	Aruna, Bhagya
Optimum planting time/ population	-	Sow 12-15 kg seeds/ha in the first fortnight of July or even late in the season
Presowing seed treatments	-	Soak the seeds in water for 24 hours before sowing for better stand establishment
Fertiliser use	-	Place 20 kg N/ha at sowing and top dress 20 kg N/ha 4 weeks after sowing

CHAPTER III

3.0 HORTICULTURE RESEARCH IN ARID REGIONS

3.1 INTRODUCTION

3.1.1 Arid horticulture offers an appreciable scope for stabilising as well as augmenting the economic base of the desert dwellers. At present, there are hardly any onchards in the arid region except natural plant communities of wild ber and kair (Capparis decidua). Low rainfall conditions make the arid regions the only possible location in India for production of dates which are heitherto being exclusively imported mainly from the Middle East countries. The climatic conditions of the districts of Jaisalmer, Barmer, Bikaner and Kutch are the best available conditions for the production of dates in India. Apart from this, fruits like ber, pomegranate, guava and custard apple start their flowering in the beginning of the monsoon and harvest is completed before the onset of dry weather. Favourable climatic condition and disease free nature of the environment have earned a widespread reputation for some of these fruit crops. Brackish waters are quite suitable for fruit crops like datepalm, pomegranate, ber, fig, guava etc.

3.1.2 Under rainfed conditions, fruit growing is possible only by following watershed management concept in situ runoff concentration. People in arid regions particularly in deserts have used this technique for growing fruits. The khadins in Jaisalmer, which are low lying basins collecting runoff from surrounding catchments make further possible cultivation of some hardy fruit crops.

3.1.3 The in situ runoff concentration technique is most suited particularly for the fruit crops because (i) once established they continue to produce for many years and (ii) being deep rooted, they are able to utilise the moisture stored in lower soil layers and can produce optimum crops even in low rainfall years.

3.2 OBJECTIVES

3.2.1 For arid region, main objective is to identify types of horticultural crops which can evade adverse weather conditions having characteristics like deep root system, shedding of leaves during moisture stress period and limiting flowering and fruiting period during monsoon and winter season.

3.3 RESEARCH ACHIEVEMENTS

(a) Ber

(i) Standardization of agro-techniques for ber : Research work conducted at the CAZRI has shown that ber is a fruit crop which can give production both in irrigated as well as under rainfed conditions. Whole technology for cultivation of ber has already been standardised at CAZRI. Experiments initiated in this direction have revealed that yield under irrigated conditions is approximately double as compared to rainfed conditions. Performance of some varieties is illustrated in Table 1.

Table 1 : FRUIT YIELD PER TREE UNDER RAINFED AND IRRIGATED CONDITIONS IN CASE OF SOME BER CULTIVARS (5 YEAR OLD)

Cultivar	Rainfed yield(kg)	Under irrigation yield(kg)
Gola	45-50	85-110
Mundia	55-60	80-140
Seb	50-55	30-45
Jogia	45	60-80

Gola, Mundia, Seb and Jogia cultivars are the earliest in fruit maturity compared to other cultivars and this character helps in successful cultivation of ber crop in arid region. As many as 80 cultivars of ber are under further evaluation.

Research work done at the Haryana Agricultural University, Hissar has shown that cultivars Gola, Sandhura, Narnaul and Seo are the earliest for Haryana conditions.

(ii) Pruning technique : Pruning of ber in 2nd week of May has been found promising and restricts the size of the plant, which further enables it to fight adverse conditions.

(iii) Propagation : A technique has been developed at CAZRI by which an orchard can be raised within five months as against more than a year required under the conventional system. This method facilitates survival in transplanting due to least root damage. For transporting plants for long distance a poly pack method has also been evolved.

For Haryana and Punjab conditions ring budding has been found most promising.

iv) Control of pests and diseases : Fruitfly is the major pest of ber and systematic insecticides application like Rogor, Dimecron and Matasystox at 0.03% a.i. gives complete control with three sprays. For powdery mildew, Karathane (0.1%) has been found to be very effective.

v) Cultivation of Ber through runoff concentration technique: Usually ber requires 4-5 irrigations for its optimum production under rainfed conditions. Research conducted at CAZRI has shown that 56 m^2 catchment area with 5% slope is the best right from establishment to growth and fruiting. This technique provides runoff supplement varying from 200-400 mm in a addition to local input. This technique offers promise to extend ber cultivation to large areas of our rainfed lands.

vi) Economics of Ber cultivation : The cost of cultivation of ber for one hectare from the year of establishment and maintenance through tenth year, gross income/ha and net profit and loss upto tenth year are given in Appendix I. The net profit ranges from Rs.1,425/ha in the third year to as high as 28,100/ha in the tenth year. The life span of ber orchard is estimated at 45 to 50 years.

(b) Potential of Date Palm : Dates worth Rs.2.76 crores were imported in India during 1965-66 which has gone up recently to about four crores of rupees annually. This has been causing a heavy drain on the national exchequer. Date palm was introduced at the Central Arid Zone Research Institute, Jodhpur in the year 1968 to ascertain the possibility of its commercial cultivation in this region. It was done on the basis of climatological parameters which revealed that Western Rajasthan is an ideal location for its cultivation.

i) Climate : Successful date cultivation requires moderate winter temperature, long hot summers etc. mature the fruit and little rainfall and high vapour pressure deficit during fruit ripening period. The heat requirement to ripen the fruit differs with the cultivars and ranges from 4200 to over 5000 heat unit summation above the base temperature of $50^{\circ}F$. Trials at the Central Arid Zone Research Institute, Jodhpur have shown that date palm flowers during end of February to early March and the berries mature by the end of July. The heat unit

accumulation during this period is from 5510 in Kutch, 5758 in Jaisalmer, 5886 in Barmer, 6196 in Jodhpur to 6365 Bikaner (Table 2).

Table 2 : HEAT UNIT ACCUMULATION WITH REFERENCE TO DATE PALM

Districts	Heat unit accumulated in degree days (base 50°F)		
	March to June	March to July	March to August
Jaisalmer	4524	5758	6914
Barmer	4692	5886	6999
Bikaner	5041	6365	7593
Jodhpur	4995	6196	7307
Kutch (Bhuj)	4443	5510	6530

It is evident from the above table that successful date palm cultivation is possible in Western Rajasthan wherever assured irrigation facilities exist.

ii) Varietal evaluation : Four varieties viz. Halawy, Shamran, Khadrawy and Medjool were planted in the year 1968 for their evaluation under the agroclimatic conditions of Jodhpur. Spathe opening was the earliest in Halawy (Feb. 27), followed by Shamran (March 4), Medjool (March 16) and Khadrawy (March 20). Full doka stage (fruits turning from green to yellow) reached between June 20-25 in all the varieties. Maximum berry size at full doka stage was in Medjool followed by Halawy, minimum recorded in Shamran (Table 3). The average yield per palm was 75 kg in Shamran, 70 kg in Halawy, 20 kg in Khadrawy and 30 kg in Medjool. Variety Halawy comparatively performed well among all the four varieties tried with regard to berry size and yield. Moreover the fruits of Halawy are acceptable in doka stage because it does not have stringency, present in berries of other varieties making them unacceptable.

Table 3 : FLOWERING AND FRUIT DEVELOPMENT IN SOME DATE PALM CULTIVARS

Cultivars	Spathe opening	Full doka stage	Physical measurement at full doka stage berries Length x diam(cm)	Wt.per berry (g)	Pulp stone ratio	Yield Palm (kg)	Appearance of doing stage(if rains are delayed
Halawy	Feb.27	June 20	3.9x2.1	9.9	8.5	70 kg	2nd week of July
Shamran	Mar.4	June 22	3.8x2.1	9.1	6.0	75 kg	2nd week of July

1	2	3	4	5	6	7	8
Khadrawy	Mar.20	June 25	3.3x2.1	8.6	8.5	20 kg	3rd week of July
Medjool	Mar.16	June 24	4.0x2.3	12.1	10.1	30 kg	3rd week of July

iii) Strand thinning : Fruit bunches, if allowed to develop naturally produce small sized berries and sometimes they get spoiled due to compact bunches. Trials conducted at CAZRI have revealed that thinning should be done upto 28-30 strands per bunch as against unthinned having 40 or more strands. There is no reduction in yield, with slight increase in size which ultimately adds to the quality of fruits. Thinning should be done within a month of fruit set.

iv) Processing of doka barries to prepare dry dates (Chhuhara) : Due to the occurrence of rain in July, the berries do not attain dang stage, therefore, they are to be processed for making dry dates. For this doka berries are to be kept in boiling water for some time. The boiling time has been standardized to 20 minutes by which the final product of good quality can be prepared without losing much sugars in the leachate.

v) Economics of Date Palm cultivation : The data on expenditure and income from date palm cultivation are given in Appendix II. It will be seen that generation of income starts forthcoming from third year onwards (Rs.2300/ha) and attains as high as Rs.17,000/ha in the 9th or 10th year.

vi) Performance of date palm in Punjab, Haryana and Gujarat States : Under Abohar conditions, Halawy followed by Khadrawy and Barhee were found to be the best. In Hissar, Hayani, Shamran, Khadrawy and Halawy performed best. In Mundhra (Gujarat) introductions have been made, however, their evaluation is yet to be done.

vii) Propagation : Propagation is the major handicap in extension of date palm cultivation. In date palm, propagation is through suckers. A date palm plant hardly gives 10-30 suckers in its whole life time and this constitutes a limitation for propagation. A scheme under Department of Science and Technology is in progress at Department of Botany, University of Jodhpur in collaboration with CAZRI, Jodhpur, to multiply suckers of date palm through tissue culture.

Table 4 : LIST OF DATE PALM CULTIVARS INTRODUCED AT CAZRI, JODHPUR

1.	Halawy	9.	Sedami
2.	Khadrawy	10.	Umshok
3.	Shamran	11.	Gizaz
4.	Medjool	12.	Bikaner
5.	Dayari	13.	Muscat II
6.	Zaidi	14.	Bint Aisha
7.	Abdul Rehman	15.	Muscat I
8.	Pakistan	16.	Barhee

(c) Pomedranate

Assessment of local cultivars of pomegranate viz., Jodhpuri, Red, Saharanpuri and Jalore seedless has shown that Jalore seedless to be most promising which has sweet and soft seeds under Jodhpur conditions. For Haryana, cultivars, Nabha, Chawla, Jodhpuri and Kandhari have been found most suitable.

New introductions of pomegranate have been made from Afganistan and other areas and their performance is being studied under Jodhpur, Hissar and several other places. It is hoped that it will be possible to select a promising type tolerant to cracking and having sweet and soft seeds.

i) Propagation : Propagation in pomegranate is usually through semi-hard wood cuttings. This method of propagation is quite popular in all the states.

1.	Spanish Red	8.	Kandhari Anar
2.	Gulsha Rose Pink	9.	Gurgaon selection
3.	Appuli	10.	Sarkh Anar
4.	Gulsha Red	11.	Kharki
5.	Badana Bosek	12.	Bedana sedana
6.	Shirin Anar	13.	Soor shaker
7.	Kazakai Anar	14.	Jalore seedless

(d) Guava (Psidium quaiava L.)

It is another fruit crop which can be adjusted to dry conditions through crop regulation where the most active growth phase of fruit plant is made to coincide with the monsoon when soil moisture stress is minimum. Best thing would be to harvest the fruits in December-January and leave the orchard unirrigated through summer. This would put the plant under quiescence and spring flowering shall be eliminated. Some of the promising cultivars for desert areas are Lucknow-49, Banarsi Surkha, Tehsildar, Misri and Allahbad Safeda.

(e) Fig

Fig is another fruit crop which can grow successfully in arid and semi-arid regions. Not much work on fig has been done under arid conditions except two cultivars, namely, Brown Turkey and Black Ischia are being evaluated for their performance at University of Udaipur, Udaipur. Nutritional studies are also in progress at Udaipur and the trial is still in initial stage.

(f) Custard apple

Sitaphal (Annona squamosa) is hardy fruit crop which needs to be tried in arid region. This fruit crop grows wild in some parts of Rajasthan. Five selections from wild Custard apple growing areas i.e. Sikar, Chittorgarh, Kumbalgarh etc. have been made at the University of Udaipur, Udaipur and are being evaluated.

(g) Phalsa

Phalsa (Grewia asiatica) is also hardy fruit crop which can tolerate adverse weather conditions of arid region. It flowers in February and fruits are ready for harvest by May. It has no problems of insects and diseases. There is need to evolve better types with big fruits and short ripening period. Research work on propagation by stem cuttings at Udaipur has shown that quick dip method with 1000 ppm IBA gave maximum success in rooted cuttings.

Two strains have also been introduced at University of Udaipur, Udaipur for their evaluation.

(h) Lasora (eapordia myxa)

It is a drought tolerant crop with no need for irrigation after the growth of one season. Flowering take place in February and fruits are ready for harvest in April-May well before the hottest summer months during which it sheds off leaves. Some collections have been made at University of Udaipur, Udaipur and CAZRI, Jodhpur for evaluation.

(i) Kair (Caparis decidna) It is a xerophytic bushy plant, found wild in deserts. It is very popular with housewives for its conversion into excellent quality pickles. It is also quite rich quality-wise. There is need for clonal selection.

3.4 POST-HARVEST TECHNOLOGY AND SAFE STORAGE OF FARM PRODUCE

3.4.1 Improved post-harvest technology is essential both for getting the farmer the maximum return for his labour and also for preventing spoilage. In periods of bumper production of ber fruits in good years of rainfall, the market slump can be averted through channelising excessive produce for manufacture of processed products thereby imparting stable market for the fresh fruits.

3.4.2 To this end, the processes for the manufacture of Jam, Squash, Ber preserve and dehydrated bet etc. from fresh ber fruits have been standardised at CAZRI.

3.4.3 The shelf life of improved ber varieties like Gola, Seb, Mundia is hardly one week and this become a limiting factor for transportation to distant markets. Therefore, research into storage of farm produce should take into account preservation of shelf life for long periods without deterioration of quality. High density polythene packing and appropriate marketing also needs attention.

3.4.4 Apart from Ber, improved post harvest technology system will have to be developed for each major farm produce so that the value-added produce goes out of the village for sale.

3.5 EXTENSION PROGRAMME

3.5.1 Distribution of plant material : As a result of technology standardized for ber cultivation at CAZRI, lot of interest was generated

in planting of ber. To meet this demand fruit nurseries at Regional Station of the Institute have been initiated and during 1980, 7000 budded plants of ber were distributed. Details of other fruit plants distributed are given in Table 6. The technology on ber has also been transferred to the field of Operational Research Project area of the Institute and a farmer has also taken up multiplication of ber plants.

Table 6 : NUMBER OF FRUIT PLANTS SOLD FROM HORTICULTURE NURSERY (CAZRI JODHPUR)

	1977	1978	1979	1980
Ber (Grafted)	500	2,500	4,000	7,000
Guava (Grafted)	10	15	15	23
Guava seedling	150	200	400	660
Lime seedling	200	4,000	1,000	2,350
Pomegranate seedling	150	180	500	690
Lasoda seedling	-	200	500	680
Mosambi (Grafted)	-	25	100	288

3.5.2 Technology for cultivation of ber has already been standardised and now it needs to be extended to farmers on large scale. To implement this, State Agriculture Departments ought to arrange multiplication of grafted ber plants for large scale distribution.

3.6 FUTURE LINES OF RESEARCH

(i) Evaluation of date palm needs to be intensified in different soil-climate and groundwater situations including Lathi series areas.

(ii) Breeding programme in ber should be undertaken for enhancing shelf life and organoleptic properties and incorporating resistance to fruitfly and powdery mildew.

(iii) There is an urgent need to intensify and breed if necessary suitable cultivars of pomegranate, phalsa, fig, guava, Annona squamosa, (Sitaphal) and muberry which can withstand adverse weather conditions.

(iv) Research work to identify promising types from indigenous plants needs to be taken up with reference to the following naturally growing wild plants either for their edible fruits or pods.

1)	Zizyphus nunrmularia (Jhar.Ber)	-	fruits
2)	Zizyphus rotundifolia (Bordi)	-	"
3)	Cordia myxa (Gonda)	-	"
4)	Cordia gharaf (Gundi)	-	"
5)	Carissa carandas (Karaunda)	-	"
6)	Grewia subineaqualis (Phalsa)	-	"
7)	Salvadora oleoides (pilu, Jal)	-	"
8)	Capparis decidua (Kair)	-	"
9)	Prosopis cineraria (Khejri)	-	Pods
10)	Acacia senegal (Kumat)	-	Seeds
11)	Syzigium cuminii (Jamun)	-	Fruits and dyes

(v) Work on dryland horticulture by including crops other than ber to develop technqie for rainfed production needs to be intensified.

(vi) Research work on vegetables Citrullus fistulosus (Tinsi, Tinda), Coccinia grandis (Gol, Golan), Cucumis melo Var momordica (Phoot), C.prophetarum (Khat kachario). Cucumis calosus (Kachri) Luffa cylindrica (Chikni Turai) Luffa acutangula (Kali Turai), Citrullus lanatus(Mateera) Momordica balsamina (Barh-larelo), M.charantia (Karela) needs to be intensified.

(vii) Research work needs to be taken up to identify cultivars of various fruit crops which can withstand salinity with deterimental effects on their productivity e.g. Citrus selection, ber and date palm.

(viii) Investigations on oil yielding plants such as Cirtullus colocynthis and Salvadora oleoides and Salvadora persica.

(ix) Post harvest technology research for various farm produce in order to generate maximum returns to the farmer, needs to be intensified.

Appendix I

Cost of cultivation of Ber for one hectare

(A) Establishment of orchard

	Item	Amount	Rate	Total cost (Rs.)
i)	Fencing			
ii)	Digging of pits - Labour	12 men	Rs.7/- per lab	84.00
iii)	Filling of pits -			
	I. Manure	250 ft.	Rs.145/100 ft	362.50
	II. Aldrine	25 ft.	Rs.0.50/kg	12.50
	III. Labour	12 men	Rs.7.00/man	84.00
iv)	Cost of plants	250 + 10 plants	Rs.3.15/plant	819.00
v)	Plant protection measures	250 plants	Rs.1.00/plant	250.00
vi)	Labour for planting	5 men	Rs.7.00/man	35.00
vii)	Labour for after care	1 man for one year	Rs.7.00/day	2,555.00
viii)	Miscellaneous	-		198.00
	Total cost of establishment			4,400.00

(B) Cost of maintenance in II year

i)	Labour	for one year	Rs.7.00/day	2,555.00
ii)	Plant Protection measures	250 plant	Rs.1.00/plant	250.00
iii)	Cost of watching (one man)	for 2 months	Rs.7/man	420.00
	Total cost of maintenance			3,225.00

(C) Maintenance in Third Year

i)	Labour	for one year	Rs.7.00/day	2,555.00
ii)	Plant protection	for 250	Rs.1.00/plant	250.00
iii)	Cost of watching (one labour)	for 2 months	Rs.7.00/man	420.00
iv)	Labour for picking	50 men days	Rs.7.00/man	350.00
				3,575.00

(H) Cost of maintenance for VIII year

i)	Labour	for one year	Rs.7/-p.day	2,555.00
ii)	Plant Protection measures	250 plant	Rs.2.00/plant	500.00
iii)	Cost of watching and picking (3 men)	for 2 months	Rs.7/-day	1,260.00
iv)	Cost of pruning	5 men	Rs.7/-p.day	35.00
v)	Miscellaneous			35.00
			Total	4,385.00

(I) Cost of maintenance for IX year

i)	Labour	for one year	Rs.7/ day	2,555.00
ii)	Plant protection measures	250 plants	Rs.2.00/plant	500.00
iii)	Cost of watching and picking (3 men)	for 2 months	Rs.7/- day	1,260.00
iv)	Cost of pruning	5 men	Rs.7/- day	35.00
v)	Miscellaneous			35.00
			Total	4,385.00

(J) Cost of maintenance for X year

i)	Labour	for one year	Rs.7/- p.day	2,555.00
ii)	Plant protection measures	250 plant	Rs.2.00/plant	500.00
iii)	Cost of watching and picking (3 men)	for 2 months	Rs.7.00/day	1,260.00
iv)	Cost of pruning	5 men	Rs.7.00/day	35.00
v)	Miscellaneous			50.00
			Total	4,400.00

(D) Cost of maintenance for IV year

i)	Labour	for 1 year	Rs.7.00/day	2,555.00
ii)	Plant protection measures	for 250 plant	Rs.1.50/plant	375.00
iii)	Cost of watching and picking (2 men)	for 250 plan.	Rs.7.00/day	840.00
iv)	Miscellaneous			30.00
		Total		3,800.00

(E) Cost of maintenance for V year

i)	Labour	for one year	Rs.7/day	2,555.00
ii)	Plant protection measures			375.00
ii)	Cost of watching and picking (2 men)	250 plant	Rs.1.50/plant	840.00
iv)	Miscellaneous			30.00
				3,800.00

(F) Cost maintenance for VI year

i)	Labour	for 1 year	Rs.7/-p.day	2,555.00
ii)	Plant protection measures	250 plants	Rs.1.75/plant	467.50
iii)	Cost of watching and picking (3 men)	for 2 months	Rs.7/-p.day	1,260.00
iv)	Cost of pruning	5 man days	Rs.7.00/day	35.00
v)	Miscellaneous			32.50
				4,350.00

(G) Cost of maintenance for VII year

i)	Labour	for 1 year	Rs.7/-p.day	2,555.00
ii)	Plant protection measures	250 plant	Rs.1.75/plant	467.50
ii)	Cost of watching and picking (3 men)	for 2 months	Rs.7.00/plant	1,260.00
iv)	Cost of pruning	5 man days	Rs.7.00/day	35.00
v)	Miscellaneous			32.50
				4,350.00

Income of Ber per year in one hectare

Years	Yield per plant	Total yield	Rate per kg	Total amount of years
II	3.5 kg	875 kg	Rs.2/-	Rs. 1,750.00
III	10 kg	2,500 kg	"	Rs. 5,000.00
IV	20 kg	5,000 kg	"	Rs.10,000.00
V	35 kg	8,750 kg	"	Rs.17,500.00
VI	45 kg	11,250 kg	"	Rs.22,500.00
VII	50 kg	12,500 kg	"	Rs.25,000.00
VIII	55 kg	13,750 kg	"	Rs.27,500.00
IX	60 kg	15,000 kg	"	Rs.30,000.00
X	65 kg	16,250 kg	"	Rs.32,500.00

Net profit and loss upto 10th year

Years	Total maintenance cost	Gross income	Profit/Loss
I	4,400.00	-	- 4,400/-
II	3,225.00	1,750.00	- 1,475/-
III	3,575.00	5,000.00	+ 1,425/-
IV	3,800.00	1,000.00	+ 6,200/-
V	3,800.00	17,500.00	+ 13,700/-
VI	4,350.00	22,500.00	+ 18,150/-
VII	4,350.00	25,000.00	+ 20,650/-
VIII	4,385.00	27,500.00	+ 23,115/-
IX	4,385.00	30,000.00	+ 25,615/-
X	4,400.00	32,500.00	+ 28,100/-

Appendix II

Estimated cost of establishment of date palm orchard per hectare

Items	Expenditure	Income
I year		
No. of plants/hectare = 255 planting distance 6 m x 6 m		
1. Digging of pits of 1.5 x 1.5 m @ 10 pits	2,560.00	
2. Filling of pits (including manure and labour) @ Rs.10 per pit	2,560.00	
* 3. Cost of 255 plants		
(i) Female @ 12/- 230 plant	3,060.00	
(ii) Male 25 plants @ 3/-	75.00	
4. Cost of planting 15 man days @ Rs.7/- p.d.	105.00	
5. Chowkidar, 365 man days @ Rs.7/- p.d.	2,555.00	
Total	10,915.00	Nil
Say	11,000.00	
* Provided plants are available near the site of planting		
II year		
Chowkidar 365 m.d. @ Rs.7/- p.d.	2,555.00	
Manure, insecticides, fungicides etc.	1,000.00	
Total	3,555.00	Nil
III year		
Chowkidar 365 m.d.	2,555.00	Expected yield 5 kg per palm from doka 1150 kg
Bird scaring, harvesting marketing etc. 50 m.d. @ Rs.7/-	350.00	
	1,000.00	To be sold @ Rs.2/- per kg
Manure insecticides etc.	3,905.00	Rs.2,300.00

IV year-V year

Chowkidar 365 man days	[illegible]	150 kg
Pollination 20 m.d. @ Rs.7/- p	[illegible]	[illegible] = 3,450
Bird scaring, harvesting, marketing, etc. 50 m.d.	[illegible]	[illegible] @ Rs.2/- [illegible] kg = Rs.6,900/-
Manure, insecticides etc.		
	4,045.00	

Say Rs.4,100.00

Profit Rs.6,900-4,100 = Rs.2,800.00

VI-VII year

Chowkidar 365 m.d.	2,555.00	An yield 40 kg per palm doka fruits = 9,200 kg
Pollination 20 m.d.	140.00	
Bird scorer, harvesting, marketing etc.	350.00	
	350.00	Income @ Rs.2/- per kg = Rs.1,8400/-
Manure etc.	2,000.00	
	5,045.00	

Say Rs.5,100.00

Profit 18,400-5,100=Rs.13,300.00

IX-X Year	6,000 (Approx.)	50 kg per palm = 11,500 kg @ Rs.2 kg =2,300.00

Profit 23,000-6,000 = Rs.17,000.00

Note i) Yield is obtained only from 230 palms (female)

ii) Irrigation charges have not been included

iii) Margin of profit is more in processed dry dates but initial capital investment of dehydration plant has to be incurred; which will largely depend upon the size of unit.

CHAPTER IV

4.0 FORESTRY RESEARCH IN ARID ZONE

4.1 HISTORICAL BACKGROUND

4.1.1 Arid zone may not be eminently suited for raising forestry, yet trees and shrubs have a very valuable and in certain respect play a key role in the economy and longterm productivity of the region. Besides providing the much needed fuel and timber, trees and shrubs have the potential of forming a truely healthy combination with the more widespread landuses namely the farming and pasture lands. As their productivity does not get affected by droughts, they introduce a very important element of stability and some insurance for survival. These offer an effective as well as a remunerative means for fighting shifting sand dune menace. Trees are an ideal material for wind-breaks around irrigated farms. They can form attractive avenues along roads, canals and railway lines etc. with multipurpose benefits. The desert dwellers are conscious of the potential of this natural wealth and to a good measure the same is being realised also. But this concern does not take the form of a concrete action due to several reasons.

4.1.2 The research in arid zone forestry made its humble beginning in early fifties when the Government of India, giving high priority to the problem of the 'Rajputana Desert', established a Desert Afforestation Research Stations (DARS) at Jodhpur. The main functions of this station were to conduct afforestation research and to carry out development and extension forestry i.e. creation of cases of vegetation and shelter belts along main high ways and district roads, standardization and demonstration of afforestation techniques for denuded areas unfit for cultivation. During the ensuing reorganisations and with the creation in the year 1959 of CAZRI, emphasis was shifted from demonstrational aspect to fundamental and applied research with following as the main objectives :

- Selection and introduction of suitable indigenous and exotic trees and shrub species, which can propagate and regenerate quickly and give high yield of fuel and fodder.

- Production of plant material economically and with minimum use of water.

- Study of the important trees and shrub species occurring in the desert regions, regarding their extent, silvicultural characteristics and natural vegetation.

- Develop practical methods of afforesting different sites met within the desert region.

- Develop and standardise the technique for stabilisation of shiftings and dunes, wind breaks and shelterbelts, including the determination of most suitable composition and efficient form of wind breaks and shelterbelts to provide protection to the cultivated areas and check wind erosion.

- Study the effect of lopping on leaf fodder yield and growth and behaviour of desert trees and shrubs.

- Forest Management systems including the problems of pasture improvement and grazing management in the Rajasthan desert.

4.2.0 RESEARCH AND DEVELOPMENT EFFORTS

4.2.0.0 CAZRI after conducting a series of experimentation, for the last two and half decades, in the different localities of Western Rajasthan viz. Jhunjhunu, Sardarshahar, Narhar, Churu, Sri Dungargarh, Suratgarh, Barmer, Gadra Road, Bikaner, Jodhpur and Pali, having rainfall varying from 150 mm to 450 mm, has standardised the most suitable techniques for afforestation of various habitats of this region. A brief resume of work done so far is given here.

4.2.1 Introduction and Selection of Fast Growing True Species

4.2.1.1 The local tree species of the region are not only a few but are extremely slow growing. Therefore, greater attention was focussed on introduction and selection of exotic fast growing tree and shrub species from iso-climatic regions of the world. In this effort about 114 *Eucalyptus*, 65 *Acacia*, and 85 miscellaneous species of other genera from various countries including Mexico, USA, Latin American, U.S.S.R., Africa, Israel and Middle East were introduced. As a result a number of exotic tree species like *Eucalyptus camaldulensis*, *E.terminalis*, *E. melanophloia*, *Acacia tortilis*, *A. raddiana*, *A. salicina*, *A. sieberiana*,

A. aneura, Colophospermum mopane, Dichrostachys clomerata, Brasilettia mollis, and Prosopis juliflora (Provenance Israel, Peru and Chile) have emerged very promising for arid region.

4.2.1.2 Of all the exotics Acacia tortilis have been adjudged as the best fuel-cum-fodder species for dry zones and when felled in the tenth year of planting is estimated to yield 40 tonnes of air-dried fuel per hectare. It has found a niche not only in Western Rajasthan but also in other States including Punjab, Haryana, UP, M.P., Gujarat, Tamil Nadu, A.P., Orissa, Bihar, Maharashtra, Karnataka, Delhi, J&K, West Bengal and H.P.

4.2.1.3 The seed and plant material of Eucalyptus camaldulensis supplied from CAZRI has been grown extensively by Andhra Pradesh State Forest Corporation and great demand for it has since followed from Tamil Nadu, Rajasthan, Gujarat and Haryana Forest Departments.

3.2.1.4 Acacia salicina, A. aneura, Brasilettia mollis, Hardwickia binata and Colophospermum mopane have been identified as fodder trees most suited for 300-350 mm rainfall zone. Whereas Dichrostachys clomerata has been adjudged the best species for reclamation of wastelands in view of profuse root suckers produced by the plant.

4.2.2 Propagation Methodology

4.2.2.1 Seeds sown direct at sites have in many cases have sprouted but failed to establish. Cuttings of Tamarix articulate, Calligonum polygonoides, Commiophora mukul, Acacia senegal, Euphorbia antisyphilitica have only given good results. As regards Acacia senegal, though it could also be raised by cuttings, it is advocated to raise the plantation of this species by raising seedlings and transplanting for better establishment and faster growth.

4.2.2.2 Trials on seedlings raised in polythene bags, G.I. containers, sundried earthen bricks and earthen pots have been conducted and earthen pots have been totally discarded as the seedlings have a tendency to develop coiled root system which is not desirable for tree development. Sundried earthen bricks were recommended mainly for sand dune afforestation but now seedlings raised in polythene bags are recommended mainly because of transportation difficulties and breakages on transit. G.I. containers give very good results, but of late they are becoming too

costly. G.I. sheets are not easily available in the local market. Perforated polythene bags have been found to be ideal for raising seedlings and easy to transport.

4.2.3 Seedling Production

4.2.3.1 Nursery techniques for raising plant material of both indigenous and exotic tree species have been standardised which includes the use of (i) a well balanced potting mixture of sand, farm yard manure and clay inequal proportion, (ii) cylindrical metallic bottomless containers, (iii) watering @ 9 liters at a time per set of 50 containers, (iv) providing overhead shade during hot season, (v) construction of cemented beds, and (vi) raising of live windbreaks around the nursery.

4.2.4.0 Tissue Culture Techniques in Propagation and Improvement of Plants of Arid Zone

4.2.4.1 The plant wealth of desert areas (arid or semi-arid) has a serious drawback in having slow growth and regeneration capacity coupled with very low economic yields. These characteristics of the desert plants make them either unexploited or underexploited as far as economic yields are concerned. As the people of these areas face acute shortage of fuel wood, fodder, feed and drugs etc., there is urgent need to evolve ways and means to have rapid multiplication methods and increase through breeding the regeneration and growth capacity coupled with higher economic yields.

4.2.4.2 Tissue culture method (growing of the plant tissues in artificial culture and differentiating them under in vitro conditions) holds a great promise for achieving of the above objectives. It is an important efficient and reliable method of vegetative propagation for a number of reasons :

i) In breeding programme, it is sometimes desirable to perpetuate intact a particular unique genotype having all desirable characteristics.

ii) Vegetatively propagated plants are liable to accumulate systemic viral, bacterial or fungal infection; disease free individuals often obtainable only in small numbers will need multiplying up through tissue culture.

iii) In many species new hybrid cultivars arise as single plants, either selected during breeding programmes or as a result of chance mutation; these require multiplying up as quickly as possible for testing and ultimate commercial production etc.

4.2.4.3 In the light of the advantages offered by the tissue culture method, the following are some important plants that can bolster up the economic conditions of the arid zone dwellers :

i) Prosopis cineraria (Khejri)
ii) Commiphora mukul (Guggal)
iii) Zizyphus mauritiana (Ber)
iv) Pheonix dactylifera (Khajoor)
v) Simmondsia chinensis (Jojoba)
vi) Tecomella undulata (Rohira)
vii) Euphorbia spp.
viii) Calotropis procera (Aakra)
ix) Eucalyptus spp.

4.2.4.4 The inherently slow growth characteristics of Khejri, the prize tree of the arid regions, can be overcome through adoption of the tissue culture techniques. It can help in developing large number of khejri plants that have the capacity to grow fast.

4.2.4.5 Khajoor and Jojoba have a special place in arid zones but they have specific problems too - the major being the identification of the sex at initial stages so that a proper male : female ratio could be maintained in the field for maximum fruit/seed production. Tissue culture helps in the multiplication of

the desired sex in large numbers and hence help in keeping the required sex ratio in the field.

4.2.4.6 Euphorbia and Akra can be understood better for their biochemical pathways for hydrocarbon by this method as it helps in having a complete plant passing through various stages of differentiation and development. So this method gives an opportunity to manipulate the most important stage which is economically important for exploitation.

4.2.5.0 TISSUE CULTURE IN TREE IMPROVEMENT : Tissue culture has special role to play in the trees of arid zone through haploid culture, polyploidy induction, embryo culture, protoplast hybridisation, mutant selection and gene pool preservation.

4.2.5.1 Haploid Culture : In Prosopis cineraria in breeding to homozygous lines for controlled hybridisation is not practical because of the large period between successive generations and others self fertilisations/pollination may not be possible (Calotropis) because of various reasons. To get rid of problems like this, a technique now frequently considered is doubling of the chromosomes number in either naturally occurring or artificially obtained haploid plants. Haploid trees have reportedly been produced artificially by remote hybridisation, irradiation, chemical treatment of pollen and lately from culture.

4.2.5.2 Polyploidy : Induction of polyploidy through tissue culture in trees is important as polyploids show higher growth rates than the diploids.

4.2.5.3 Embryo Culture : The main objective of this technique is to germinate embryos that would not normally germinate because of incompatibility between the embryo and material tissue, as is common in seeds resulting from inter-specific hybridisation. In this direction hybridisation between Prosopis cinerario x P. juliflora for the selection of fast growing and higher fodder yielding hybrids assumes special significance.

4.2.5.4 Mutant Selection : Presently mutants of tree species are obtained mainly by irradiation or application of mutagenic chemicals to pollen, seeds, or whole plants, which are less efficient and laborious. This favours the use of cell suspension and subsequent cell planting techniques, because it allows easy handling of large populations of cells and embryos in in vitro conditions. This method can be applied to all trees/plants of importance in arid zone.

4.2.5.5 Gene Pool Preservation : Through tissue culture, it would also be possible to preserve the vanishing species. Tissue culture could have an important function in the establishment of gene banks by using deep freeze storage techniques, particularly for plants that normally are propagated vegetatively i.e. those which are infertile and therefore cannot be stored as seeds.

4.2.6.0 Transplantation Technology

4.2.6.1 Different methods viz., (a) Direct sowing seeds at site (b) transplanting 10 to 12 months seedlings in pits of 45^3cm and (c) planting cuttings of the species have been tried in arid zone. It has been observed under arid zone conditions, transplanting seedlings have been found to be successful and the best.

4.2.7.0 Silvical Characteristics of Selected Tree and Shrub Species

4.2.7.1 The results of silvical studies on the important arid zone **tree and shrub species** indicated that under rainfed conditions transplanting 6-9 month old seedlings have significantly given better performance over direct seeding at site and transplanting of two year old plants in 60^3cm pits excavated and refilled with weathered soils. Thus in arid region younger seedlings successfully withstand the physical limitations of the environment. The planting of young seedlings, instead of the general practice of using older transplants will, therefore, substantially reduce the cost of production of nursery stock. Planting at different periods did not show any marked effect on the seedling survival and growth in height as the establishment depends

mainly on the rainfall pattern. The best planting period synchronis with the onset of monsoon. Compared with direct seeding, transplanting proved to be on assured method of reboisement. It is better to follow an initial wider spacing 5x5 m for conducive plant growth and to obviate the necessity of early thinning.

4.2.8.0 Sand Dune Stabilisation

4.2.8.1 Unstabilised sand dunes shift their locations not only to encroach over the roads, railway lines, villages and clog the irrigation canals, but the drift sand also covers the food crops occassionally in vast stretches of cultivated desert lands. Techniques for sand dune stabilisation have been evolved. The rehabilitation of marching sand dunes through revegetating involves three distinct processes viz., (a) Protection against biotic interference by fencing the area, (b) establishment of microwind breaks on the windward side of dune in 5 m parallel strips or 5 m chess boards, and (c) sowing of grasses and transplanting (with the onset of monsoon) of adopted trees and shrubs raised in earthen bricks or in polythene bags on the leeward side of microwind breaks.

4.2.8.2 Recent studies have revealed that the benefit-cost ratio for sand dune stabilisation technology in areas like Udramsar and Jhunjhunu works out to be 1.83 : 1 and 3.58 : 1 respectively. Thus returr annually on per rupee investment is higher in these areas. However, returns start accruing after an initial period of say 5-10 years. Detailed investigations on economic return are still required.

4.2.9.0 Afforestation on saline soils

4.2.9.1 Salt affected soils have caused problems for agricultural production in India. As mentioned in the chapter VIII on soil and ground water salinity problem, about 4 lakh hectares in Pali region have mean profile salt concentration ranging from 15 to 54 mmho/cm (EC). Therefore, reclamation of such areas through well adapted salt tolerant species of plants assume importance.

4.2.9.2 As part of revegetation programme at Jaswantgarh RM&SC area, which has shallow and highly saline soils and infested with Suaeda

fruticosa, trials were undertaken with economically useful and salt tolerant fodder species such as Chenopodium auricomum, Atriplex nummularia, Dichrostachys nutans and Colophospermum mopane. These plant materials were raised as seedlings and rooted cuttings. The results of initial establishment are tabulated below : -

Species	Year of Planting	Survival per cent	Mean height cm	Range in height growth cm
1. Atriplex nummularia				
Seedling	1980	43.3	42.3	19-81
Cuttings	1980	100.0	50.3	20-75
2. Chenopodium auricomum				
Seedlings	1980	66.1	82.4	20-132
3. Dichrostachys nutans				
Seedlings	1979	68.0	89.1	20-130
4. Colophospermum mopane				
Seedling	1979	72.0	-	-

4.2.9.3 The rooted cuttings of A. nummularia had the highest establishment and produced an average of 6 coppice shoots with a maximum of ten per cutting. Out of the seedlings raised, the maximum height was attained by Chenopodium auricomum (82.4 cm) and upto a maximum of 136 cm over a period of six months of transplantation.

4.2.9.4 Further initial screening of various shrubs and tree seedlings for their response to saline water irrigation at Pali and Jadan areas, Simmondsia chinensis, Atriplex nummularia. Chenopodium auricomum, Prosopis alba were grown in shallow soils at Pali and provided supplemental irrigation from available saline water from tube well (4,000 mmhos) during first year of establishment. The data on performance are presented below :

Species	Origin	Survival %	Mean height (cm)	Crown dia. (m)	Average No. of branches per plant	
					Main branch	Smaller branches
Atriplex nummularia	Australia	88.9	79.8	1.6	3	38
Simmondsia chinensis	Arizona USA	91.7	25.2	0.5	2	6
Prosopis alba	USSR	100.0	107.4	1.2	3	9

4.2.9.5 At Jadan, the site had shallow spils with three levels of salinity namely low, medium and high down the slope. The table below gives the species selected and their relative performance under different levels of salinity.

Species	Survival percentage under salinity levels		
	Low	Medium	High
Atriplex nummularia	93.8	87.5	25.0
Chenopodium auricomum	75.0	62.5	25.0
Simmondsia chinensis	25.0	12.5	-

4.2.10.0 Management of Salt Affected Soils

4.2.10.1 Apart from non-cash inputs like trials with salt tolerant plants for reclamation of salt affected soils, proper management of such soils is equally important for success. Thus by ripping open the pan to a depth of 1 metre by 8 crawler type tractor followed by cross harrowing and after breaking the pan, ridges of 1 m wide at the base and 1 m high are constructed with the help of dozers. The inter ridge spaces are about 1.5 to 2 m. Planting is done on the crest of the ridges in pits so that the salts get leached down from the ridges to lower depth providing better soil conditions and rooting depth for increased transplant establishment and growth. Prosopis juliflora and Sporobolus spp. have been found most useful for establishment in saline soils.

4.2.10.2 Studies by Malcolom et al (1980) in Western Australia, showed that Malien Niche seeder gave much better establishment of salt tolerant forage shrubs of saline soils than was obtained by spreading seed on scarified ground.

4.2.10.3 In view of similar climatic and environmental conditions prevailing in India, the trials with Malien Niche seeder are likely to prove beneficial in reclamation programme.

4.2.11.0 Shelterbelt and Wind Breaks

4.2.11.1 In arid and semi-arid areas in order to moderate wind velocity (which may reach even 40 km/hr in peak summer), reduce evapotranspiration and thereby protect crops from wind damage, shelter-belts and windbreaks have been developed. Correct choice of species and adoption of appropriate techniques of establishment and maintenance could yield higher economic benefits and make shelter belts raising a remunerative practice.

4.2.11.2 Design of shelterbelts : In the design of shelter belts, the major aim is to achieve a reduction in wind velocity on the windward as well as leeward side using the minimum possible land area. They can be designed to be compact or wind proof, they can be permeable (allowing about 30% air flow) or porous (allowing 40% air flow).

4.2.11.3 When the shelter belt is impermeable to wind, all the flow is deflected upward over the belt leaving a reduced wind zone downward. It provides a greater degree of shelter immediately to leeward, but because of eddying effect, it gives comparatively short zone of effective shelter. To achieve appropriate wind velocity shelter belts should ideally be permeable with calculated width shape and height.

4.2.11.4 Permeable and porous shelterbelts are obviously more economic to establish and although they provide less absolute reduction

of velocity they do affect a greater distance downward. The vertical structure of shelterbelts depends upon the formation of tree species to have a triangular cross section, the number of rows, the distance between rows and number of trees within the row. In regard to wind speed reduction the thickness of shelterbelt is of secondary consideration Narrow shelterbelts of moderate density are as efficient as broad ones.

4.2.11.5 Keeping in view the above principles, the choice of species and growth form, the number of rows and distance between rows have been standardised. This shelterbelts of Acacia nilotica, and Dalbergia sisoo have been successfully established over 102 km. length at the Central Mechanized Farm. Suratgarh in Bikaner Division of W. Rajasthan.

4.2.11.6 Besides experimental shelter-belts in the form of roadside avenues along the principal highways were established in different parts of the region to the extent of 200 km at a cost of Rs.1,200/- row km.

4.2.11.7 The effectiveness index of tree shelte belts of Cassia siamea, Acacia tortilis and Prosopis juliflora in wind speed reduction was computed and it was found that Cassia siamea and Acacia tortilis shelter belts are useful in controlling wind speeds.

4.2.11.8 Ultimately the zone of wind velocity reduction from the belt is normally expressed in multiples of shelterbelt height. The principal shelterbelts developed above are generally separated by a distance equivalent to 20 times the height of the tallest trees. Thus a spacing of about 200 m to 300 m between shelterbelts is desirable in arid areas where tree heights seldom reach beyond 10 to 15 m.

4.2.12.0 Soil Working Techniques and Cultural Operation in Relation to Landtypes

4.2.12.1 Soil working techniques and cultural methods for establishment of plantations in different land types namely rocky, semi-

rocky and shallow soils overlying hard calcareous pans etc. have been developed.

4.3.0 AGROFORESTRY

4.3.1 The concept of Agroforestry implies the integration of farming with forestry practices on thc farm to the benefit of agriculture. It represents a sustainable land management system which increase the overall yield of the land, combines the production of crops and forest plants/or animals, simultaneously or sequentially on the same unit of land and applies management practices that are compatible with cultural practices of local population.

4.3.2 Although the terminology is new and scientifically defined the practice of growing trees in the farm and cultivation of crops in the interspaces of well adapted desert trees particularly Khejri (Prosopis cineraria) and Jharber (Zizyphus nummularia) is not new to the farmers of Western Rajasthan. They have long recognised the fertility building characteristics of trees and their symbotic effect on the good crop growth and higher yields and have pursued such approach.

4.3.3 However, there was no scientific approach in as much as the trees are permitted to grow at-random in the fields for crop cultivation regardless of appropriate compatibility and choice of crops - a sort of subsistence approach.

4.3.4 It has now been amply demonstrated that in "fragile ecosystems as the arid regions, agriculture alone would not be a stable enterprise and has therefore to necessarily seek the prop of forestry into the farming system in order to impart stability and generate assured income. However, there is need for research to continuously refine and improve the system. The shade tolerance of various agricultural species must be tested. Forest species which protect the soils but do reduce energy levels on the understorey require to be determined. Above all new breeding programmes designed to obtain in both forest tree species and crops those characteristics and attributes that are necessary for successful and efficient intercropping

4.4.0 SILVI-PASTORAL SYSTEM

4.4.1 In order to develop optimum balance between forest and pasture in the arid regions silvi-pastoral studies were undertaken at CAZRI. The main findings are as under :

4.4.2 Medium stock density of the shrub Jharber (Zizyphus nummularia) with 14 per cent of the land area covered by shrub canopy was found optimum for higher forage production yield of leaf fodder which ranged from 105-150 kg/ha. The combined yield (leaf fodder plus grass) was 100 kg/ha.

4.4.3 Grasses viz. Cenchrus ciliaris C. setigerus and Dichanthium annulatum when inter-cropped between tree species (A.tortilis, Albizzia lebbek, Azadirachta indica and Haloptelia integrifolia) spaced 5 x 5 m gave a dry forage yield of 12.5 to 20.0 g/ha at Pali, depending on rainfall distribution but had no adverse effect on the tree growth.

4.4.4 Studies on forage production in 14 to 18 years old plantation in four desert trees i.e. Khejri (Prosopis cineraria), Rohida (Tecomella undulata), Siris (Albizzia lebbek) and Kumut (Acacia senegal) on alluvial flat soils at Jodhpur revealed that highest (1.1 t/ha) grass yield was obtained from Khejri and lowest (0.6 to 0.7 t/ha) from Kumut plantation.

4.4.5 Studies on lopping intensity revealed that heavy intensity of lopping adversely affect the growth of Khejri. Another, recurrent lopping reduced the leaf fodder yield irrespective of lopping perhaps due to successive reduction in the overall surface of new shoots. Need for a period of rest between two loppings of Khejri is therefore, prima facie obvious for sustained yield of loong (leaf fodder of Khejri).

4.4.6 Fully grown (over 330 years of age) Khejri with well-spread crown is reported to produce 25 kg air dried leaves, 5 kg pods and 2 kg seeds in one year in 300-400 mm rainfall zone. Palatability ratings and nutrient contents of the leaf fodder of 16 indigenous

trees and shrubs, which are found to be browsed by different kinds of livestock in western Rajasthan, have been determined. Khejri, Jharber, babool, Pilujal and Kharanjal were reported to be highly relished.

4.4.7 In general, the protein, nutrient and mineral contents of the most of the top feed species were higher than critical levels of stock maintenance. Winter loppings of Khejri were rich in crude protein content (17.49%) as compared to summer (15.38%) and copper contents were much higher than the respective critical levels. The level of the zinc was, by and large, adequate but marginal deficiency may occur in certain situations i.e. particular growth and other metabolic functions.

4.4.8 Soil-Building Influence of Trees

Under an inter-disciplinary study the soils under canopy of different leguminous trees were studied and beneficial effects in terms of nutrient build-up have been quantified.

4.5 ECONOMIC EVALUATION OF FORESTRY PRACTICES IN ARID ZONE

4.5.1 Economic Evaluation of Sand-Dune Stabilisation

4.5.1.1 Costs and returns of the dune stabilisation programmes in arid areas like Udairamsar, Shrikolayatji, Shivbari in Bikaner district and Jhunjhunu towa in Jhunjhunu district were worked out on the basis of total stabilization package recommended by CAZRI. The package mainly consisted of protection with fencing, establishment of micro-wind breaks, afforestation with trees and grasses and after care and maintenance. Data from these research centres of CAZRI relate to the years 1958-59 to 1963-64 in case of Udairamsar, 1953-54 to 1965-66 in case of Jhunjhunu township, 1966-67 to 1968-69 in case of Shrikolayatji and 1965-66 in case of Shivbari. Farm areas in these centres were made into different compartments and each compartment was stabilised in each year. The total area stabilised for which data were collected was 184 hectares in Udairamsar, 28 hectares in

Shrikolayatji, 10 hectares in Shivbari and 154 hectares in Jhunjhunu township. Inputs and outputs were evaluated at prices averaged for the total period of the project in each area.

4.5.1.2 The cost per hectare for sand-dune stabilisation programme worked out to be Rs.552, 754, 1040 and 456, respectively for Udairamsar, Shrikolayatji, Shivbari and Jhunjhunu areas. The benefits per hectare were Rs.2,086/- in Jhunjhunu, Rs.1,560/- in Udairamsar, Rs.637/- in Shivbari and Rs.616/- ub Shrikolayatji. The benefit (net) cost ratios came out to be of higher order 3.58:1 for Jhunjhunu, 1.83:1 for Udairamsar areas and were negative for Shrikolayatji and Shivbari areas. Higher benefits in Udairamsar and Jhunjhunu areas were due to the fact that the programme was in operation for many years. It may also partly be due to larger areas under this programme in these areas. Highest benefit in Jhunjhunu can be attributed to the adaptability of Jhunjhunu dune soils for the production of "Munja" grass which did not succeed in other areas. The calculation of average pay back period revealed that it takes 13 years to fully recover the capital investment made in the programme in the beginning though the benefits will start trickling from 3rd year onwards.

4.5.1.3 Cost-benefit analysis of stabilising various types of dunes in the state of not only Rajasthan but also Haryana and Gujarat is suggested.

4.5.2 Economic Evaluation of Tree Species for Fuel Plantation

4.5.2.1 From the data collected on experiments at research farm in Pali and Jodhpur for the year 1961-62 to 1972-73; cost and benefit ratios were worked out for 4 promising tree species viz., Acacia tortilis, Azadirachta indica, Prosopis juliflora and Albizzia lebbek. The benefit-cost ratios were 1.06:1, 0.99:1, 1.71:1 and 1.12:1, respectively. Prosopis juliflora thus seem to provide greater returns than other species.

4.5.2.2 Utilising the data collected from the experiment at Pali research farm for the years 1961-62 to 1972-73, felling cycles for fuel yield were evaluated for four desert tree species, viz. Acacia tortilis, Albizzia lebbek, Acacia nilotica and Azadirachta indica.

Cost-return estimates for fuel yield at different years of felling revealed optimum time of felling of 11 years for Albizzia lebbek, 8 years for Acacia tortilis, 23 years for Azadirachta indica and 49 years for Acacia nilotica. Considering the maximum fuel yield within maximum time period and thus maximum returns, Acacia tortilis was found to exceed all the tree species under consideration.

4.5.3.0 Economics of High Yielding Perennial Pasture Grass in Arid Land of Western Rajasthan

4.5.3.1 Benefit-cost ratios and net profits were worked out and analysed for promising strains of Cenchrus ciliaris, Cenchrus setigerus, Lasiurus sindicus and Panicum antidotale utilising the experimental data collected by Agrostology section of CAZRI, Jodhpur during the years 1971-74. In the present work, summation method was used to convert all costs and benefits to a common time basis. The results indicated profitability of strains of C.setigerus as compared to others not only at prices during the experimental period but also at recent prices. The comparison of net profits per hectare per year of grasses with the competing crop of bajra showed superiority of grasses over bajra in arid areas.

4.5.3.2 Studies to work out the economics of grasses intercropped with legumes are to be conducted in different agroclimatic areas.

4.5.4.0 Economic Evaluation of Some Xerophytic Plant and Tree Species in Arid Areas

4.5.4.1 Some of the xerophytic plants which commonly grow in areas have been of significant economic potential. Given the infrastructural facilities and proper planning, some of these plants can contribute to fill the vacuum in production of agro-industrial goods.

4.5.4.2 Details of production of some of these plants were obtained during a survey of the area from available records and farmer opinions. Based on the prices prevailing in 1974 costs and returns in their production were estimated. The comparison of net annual benefit cost ratios indicated the economic justification of growing

tumba (Citrullus colocynthis) (1.01:1) and matira (Citrullus lanatus) (4.42:1) for oil, and niras (Agave americans and Agave sislana) (3.76:1) for fibre, rohida (Tecomella undulata) (0.35:1), Khejri (Prosopis cineraria) (0.46:1), siris (Albizzia lebbek) (0.65:1) for timber, gugal (Commiphora wightii) (0.18:1) and kumat (Acacia senegal) (0.13:1) for gums and rasin and phog (Calligonum polygonoides) (0.37:1) for coal manufacturing on commercial lines.

4.6.0 FUTURE RESEARCH NEEDS

4.6.1 The foregoing pages in brief outline the Status of "Arid Zone Forestry" research and technologies developed to contain the desert. On the basis of the work done a few technical bulletins have also been published for dissemination of the technical knowledge. However, looking to the vast dimension of the problem, the investigations on the following aspects, to enumerate a few, need to be intensified : -

i) Fodder-cum-fuel studies in silviculture are urgently needed rather on an intensive scale. Productivity of fodder tree species, exotic and indigenous, need to be assessed now in relation to grass production and thus, research on silvipastoral system should find priority.

ii) Agro-forestry system as already in vogue, it needs a thorough scientific analysis in desert area also.

iii) Economic evaluation of the different afforestation techniques including sand dune stabilisation, shelterbelt plantation etc. need to be taken up on priority so as to assess their soundness and economic feasibility.

iv) Genetics and breeding of trees and shrubs (specially indigenous) for better plant type should receive major attention.

v) Intensification of research on tissue culture for faster propagation of promising genotype especially in case of slow growing tree species will prove to be of great advantage.

vi) Identification of new alternative sources of plant products of medicinal, industrial, essential oil and insecticidal value need to be taken up immediately.

vii) Research to establish optimum stand of trees in relation to different land types, to obtain sustained yield of fuel and such other purposes needs to be taken up on priority.

viii) In order to protect the trees from insect, pests and disease intensification of research entomology and biological control on plant protection will be of immense help and should, therefore, receive due attention.

ix) Since the field of forestry research is vast and needs multidisciplinary approach for solution, the Agricultural Universities in Haryana, Rajasthan and Gujarat should coordinate their research efforts with CAZRI in this regard.

C H A P T E R V

5.0 ANIMAL HUSBANDRY RESEARCH

5.1 INTRODUCTION

5.1.1 Livestock rearing plays an important role in the economy of the region. For example, this sector in Rajasthan accounts for 12% of the total income of the State and the major contribution in this regard is from its arid parts. Nearly 40% of the total wool produced in the country comes from the arid zone. Animal husbandry provides partial or full employment to 2/3 of the population in this region. In addition to managing livestock, a sizeable part of the population is engaged in handicrafts industries based on animal products such as wool, skins, hair and in marketing of milk and its products.

5.1.2 The National Commission on Agriculture has taken due note of the importance of cattle wealth of the arid zone and has suggested broad policy guidelines for development of this major resource. Amongst other recommendations, it has suggested that the major lines or approach in livestock development should consist of i) reducing, if not possible containing, the cattle population in the area; ii) augmenting feed and fodder resources in the area in order to ensure adequate nutrition to the animals, iii) preventing, in a large measure, the present nomadism of cattle breeders, and iv) breed improvement through planned programmes. It also suggested that a large number of improved breeds of cattle should be transferred to the Rajasthan canal command area for maintenance and improvement of these breeds.

5.2 LIVESTOCK POPULATION AND GROWTH TRENDS

5.2.1 The population of different livestock species in the arid region of Rajasthan, Gujarat and Haryana are reported in Table 1. These show that as regards Rajasthan, the sheep and goat together constitute 51% of the total livestock, whereas in Gujarat and Haryana these constitute 33% and 15% only. In the last mentioned two states states buffaloes also occupy an important position.

Table 1 : LIVESTOCK POPULATION * (000) IN THE ARID DISTRICTS OF RAJASTHAN, GUJARAT AND HARYANA

State	Cattle	Buffaloes	Sheep	Goats	Camels	Total
Rajasthan	4,034	1,380	6,676	6,174	639	18,903
Gujarat	280	135	150	250	11	826
Haryana	514	575	206	190	91	1,576

* 1971-72 Census data except for Rajasthan for which the data pertains to census 1976-77.

5.2.2 An analysis of the livestock population over the years shows that (a) despite the dwindling grazing lands, there is a constant increase in the total numbers and (b) whereas upto 1966 by and large the population of all types of livestock show an increase, from then on the proportion of cattle has started declining and that of goat has increased greatly. So there is a discernible change in livestock composition in favour of the goat.

5.3 SOME IMPORTANT BREEDS OF LIVESTOCK

5.3.1 Though as in rest of the country, a large percentage of livestock in the arid region is non-descript, this tract is the home of a number of renowned breeds. Amongst the cattle, Tharparkar, Rathi and Gir are good dairy breeds, Kankrej and Nagori are for draft purpose and Haryana is a dual purpose breed. The buffaloes are mostly of Murrah or Mehsana breeds. The important breeds of sheep are Chokla, Pattanwadi, Magra, Marwari, Nali, Pugal and Jaisalmeri, the first two of these breeds produce medium apparel or good carpet-quality wool, whereas the remaining five breeds produce carpet type of wool only. The important goat breeds are Harwari, Parbatsar, Jhalrana, Sirohi and Beetal. The goat breeds are quite prolific but these are poor milk producers, except for the Parbatsar breed.

5.4 PHYSIOLOGICAL AND PERFORMANCE ADAPTABILITY OF DIFFERENT LIVESTOCK SPECIES AND BREEDS

5.4.1 **The arid zone posseses two serious problems of lack of water** and intense heat. Added to these is the frequent lack of fodder and

salinity of the drinking water. CAZRI has done extensive physiological, nutritional and productivity studies on animal adaptation to the arid ecosystem, and has established a physiological hierarchy of desert - worthiness among the desert sheep breeds. The Marwari, followed by the Magra, are the two most adapted sheep breeds of this desert. The rural economy of the desert will, for a long time, depend on these two sheep breeds.

5.4.2 Production characteristics of "Nali", a carpet wool sheep of north western India, have been worked out **at Hissar.** Autumn mating in Nali sheep has resulted in higher fertility in comparison to spring mating. Crossing of this sheep with an indigenous mutton breed like Mandia has not given encouraging results. Work on its combining ability with Russian Herino, and Corriedale is in progress and results achieved so far indicate remarkable improvement in wool quality.

5.4.3 A superior carpet type wool bearing strain of sheep, the "Avikalin", has been evolved by the Central Sheep and Wool Research Institute, Avikanagar, from the Rambouillet and Malpura breeds. This strain produces about 2 kg greasy fleece of 25 microns average fibre diameter and 21% medullation. Similarly, a new apparel wool strain, the "Avivastra", evolved by crossing Kambouillet X Chokla has shown satisfactory performance, with an annual greasy fleece production of 2.9 kg with an average fibre diameter of 20 microns and a medullation percentage of 14%. This strain gives 20% higher income through sale of wool alone as compared to the local breed.

5.4.4 Among the exotics, the Karakul sheep of the USSR had **adapted very well to the desert environment as shown by the studies of CSWRI Avikanagar.**

5.4.5 Of the goat breeds of this region, the Marwari is obviously the hardiest while the Parbatsar is a good mill-yielder as well as being adapted to the arid environment. Scientists of CAZRI had worked on productive performance of Parbatsar goat for the first time.

5.4.6 The age at maturity of Parbatsar breed is less in comparison with that of other Indian breeds. The average daily milk yield is fairly high, being more than a kg upto the 8th week of lactation which is similar to the yield average for Beetal does. The average lactation period in Parbatsar does is more than 6 months, which is higher than that of any goat breed found in India except the Jamnapari. The lactational yield average 131 kg in the Parbatsar breed. Kids of this breed have comparatively high growth rate, the male kids attain 12.36 kg body weight at the weaning age (6 months) under natural conditions.

5.4.7 Although some work on growth of heifers on range lands has been done by CAZRI, there is need for undertaking more comprehensive adaptation research in cattle in the arid zone. Research work conducted at HAU, Hissar indicated that half crosses of Haryana with Holestein Freisian and Brown Swiss Cattle were comparable with purebred native Haryana in their adaptive reactions to high environmental temperature, and they were able to adequately compensate for stress; however, crosses with more than 50 per cent exotic inheritance were highly prone to high environmental temperature stress.

5.4.8 The circulating LH, FSH and Prolactin level estimated in cycling and non-cycling buffaloes during the hotter and cooler months have indicated that during the hotter months, the animals which did not come in oestrus or which exhibited silent oestrus, lacked the characteristic LH and FSH peaks at the time of ovulation and also showed higher Prolactin levels. The absence of optimum FSH and LH peaks and the presence of higher prolactin levels must be due to summer stress which resulted in increased physiological infertility.

5.4.9 The Rajasthan State Camel Breeding Farm at Bikaner, so far financed by ICAR, has recently been transferred to the University of Udaipur. According to the University report, this farm needs considerable strengthening for taking up research projects. The nutritional requirements of camels have been worked out by Veterinary College, Bikaner. However, there is still great scope for conducting research on **canal with particular reference**

to its drought capacity under different conditions of soil, weather and load.

5.5 NUTRITIONAL STUDIES

5.5.1 Studies conducted at veterinary college, Bikaner, indicate that crop residues like wheat straw and jowar, bajra and maize stovers, after mixing with concentrates in suitable proportions can prove to be good rations for maintenance, growth and production of desert cattle and buffaloes. The college has also worked on certain non-conventional feeds and has recommended their use for different species of livestock inhabiting the arid zone. Suitable rations for the camel have also been formulated. With proper feeding (150-200 gm concentrate per day in addition to grazing) and management conditions, the college scientists have succeeded in obtaining two lambing in 15 months against the normal period of two years.

5.5.2 Green gram (Moong) and Black gram (Urd) straw formed satisfactory maintenance rations for non-productive adult sheep. Similarly, non-productive adult sheep and goat can be maintained on Pala leaves (Zizyphus nummularia). Studies on certain important arid zone grasses have revealed that these grasses are almost similar to non legume forages in their chemical composition. Studies on common tree leaves of the Rajasthan desert have indicated that leaves of Dhak, Packar, Kadam, Shilam can be utilised as cattle feeds. A method has been developed for stall feeding of sheep for mutton and wool production by incorporation of dried autoclaved poultry excreta in the ration.

5.6 ASSIGNMENT OF PRIORITIES IN THE ANIMAL HUSBANDRY SECTOR

5.6.1 In view of the chronic feed and water scarcity conditions in the arid zone, it is essential that proper priorities be fixed for undertaking research and development works. For example, the canal command areas must have pasture development programmes as an integral part of the package of practices there. The dairy cattle and buffaloes should, generally, be located there. Sheep and goat should share the arid and semi-arid zones, with the goat pushing deeper into the arid tract. As far as possible, animals should be

selected for survival ability, reproducibility and productivity and only well-adapted, medium to high producing animals be propagated. Goat keeping should be done on more scientific lines. The carrying capacity of the grazing land must be respected, and animal numbers should be reduced accordingly. Pasture development and fodder conservation during good rainfall years should receive adequate attention.

5.7 NEED FOR STORAGE OF HAY

5.7.1 As stated above, storage of excess fodder during good rainfall years should form the basis for developing animal industry in the desert. Since, however, the nutritive value of hay and other varieties of conserved fodder decreases with time, it remains to be seen in what proportion conserved fodder should be mixed with green fodder to provide the required TDN to different livestock species in different stages of productivity, e.g. growth, pregnancy and lactation. In this respect, the traditional farmers' practices need to be looked into.

5.8 BREEDING PRACTICE

5.8.1 It must be conceded that uptil now, there has not been a concerted effort to breed animals for high productivity, in terms of milk, meat or wool yield. In cattle, much has been made of researches on dual purpose breeds. In reality, however, the selection pressure has always been for more animal power (draught capacity) than for more milk yield. Moreover, there is hardly any pure breed, of cattle left in this region. There have been tremendous intermixing of breeds. Anyway, a proper breeding policy has to be evolved, with the objective of raising the milk output. With the coming of the canal water, western Rajasthan has now great potentialities to serve as the 'milk-booth' for the nation.

5.9 SELECTION OF ANIMALS FOR HIGH PRODUCTIVITY

5.9.1 In so far as camel, sheep and goat are concerned, selection for high productivity (draught-capacity/wool, meat and milk production) should be made from among promising, adapted animals. In sheep, improving the quantity of wool produced, rather than its quality,

should be the objective, as the carpet-type of wool produced in the region has a world-wide demand.

5.10 THE IMPORTANCE OF GOAT IN THE ARID ZONE

5.10.1 CAZRI has obtained quantitative evidence that the goat is superior to the sheep in terms of adaptation to the environment. It grows faster, breeds more efficiency, can tolerate higher salt loads, needs less water and has a liking for a wider variety of feeds, including many weeds, than the sheep. These, considered with the fact that the goat is mainly a browser and the sheep a grazer, suggest a relevant role of the farmer in the desert eco-system. CAZRI has been suggesting that the goat is not necessarily the most important biotic factor involved in desertification. The deep-rooted bias against the goat may not be wholly justified and its proper place in the agro-system of the desert needs to be redefined particularly in view of the goat's potentialities to meet the protein-gap in the country.

5.10.2 There is need to develop a really dual purpose goat breed for the entire desert region. CAZRI's experience indicates that the Parbatsar breed of goat may prove suitable in this respect. Large-scale trial of this breed is urgently warranted.

5.11 AGENCIES TO UNDERTAKE FURTHER STUDIES

5.11.1 The vast scope of developing the animal sector in the arid zone requires that coordinated research projects on animal husbandry be taken up in ICAR Institutes and Agricultural Universities in the region. Some examples of areas in which coordinated research may be fruitful are as follows :

Sl. No.	Area of research	Agencies to be involved
	A. Physiology of adaptation and Production	
1.	Response of Rathi, Tharparkar and Haryana breeds of cattle to heat stress and restricted water intake in terms of growth, reproduction and milk yield.	1. Haryana Agricultural University, Hissar. 2. Bassi Animal Research Station, Animal Husbandry Department, Government of Rajasthan.

		3. Deptt. of Animal Husbandry, University of Udaipur, Udaipur.
2.	Production physiology of desert sheep.	1. CAZRI, Jodhpur. 2. CS & WRI, Avikanagar. 3. RBS College, Agra.
3.	Water use economy and mill production efficiency in desert goat breeds.	1. CAZRI, Jodhpur 2. National Centre for Goat Research, Makhdoom (Near Mathura, U.P.) 3. Bikaner Veterinary College, University of Udaipur, Bikaner.
	B. Animal Nutrition	
4.	Evaluation of different proportions of conserved fodder in feed mixtures for optimising milk production in dairy cattle and buffaloes at different levels of moisture availability.	1. HAU, Hissar. 2. University of Udaipur, Udaipur. 3. NDRI, Station - Anand, Gujarat.
5.	Optimising nutrient availability by chemical treatment of local feeds to remove tannins, and other undesirable constituents.	1. CAZRI, Jodhpur. 2. CS & WRI, Avikanagar. 3. HAU, Hissar.
	C. Animal Disease	
6.	The most prevalent animal diseases of the region, e.g. surra in camels, enterotoxaemia in sheep, mange, worminous diarrhoea immediately after the first flush of green during the monsoon, FND in cattle etc. need to be investigated in depth, their traditional cures evaluated and ideal cures formulated.	1. Bikaner Veterinary College, University of Udaipur. 2. HAU, Hissar. 3. CS & WRI, Avikanagar.

CHAPTER VI

6.0 PASTURE DEVELOPMENT RESEARCH

Importance of forages in India's agricultural economy is obvious from the very fact that inspite of the largest cattle wealth (343 million), the animal performance is one of the lowest in the world. The obvious reason for this is the lack of sufficient amount of good quality fodders (both green and dry). In Rajasthan alone, the livestock population has increased from 9.4 to 18.1 millions during the last 20 years where as the area put to less intensive use has decreased by almost 25%. This has created a situation where animals are unable to get even one third of what they need for a maintenance ration of 4.53 kg of roughage per day plus 2.72 kg of green grass for a body weight of 227 kg.

6.1 SCOPE OF PASTURE DEVELOPMENT

6.1.1 Area of permanent pasture lands in the region is very small. For example as per latest available statistics (1977-78) in the vast tract of arid Rajasthan, only 4% of the area is under this category. However, in the more arid districts namely Jaisalmer, Bikaner and parts of Barmer mainly 60 to 80% of the area is composed of so-called culturable waste. These lands occupy mainly 50,000 km^2 area. These are considered culturable only because the soils are reasonably fertile, but climate-wise these are unfit for arable farming, and are the potential lands for systematic pasture development. Besides above, grassland development has considerable scope in the dominantly agricultural tract also. A number of studies by CAZRI concerning this tract have shown that in a number of situations, lands of very low use capability namely the dune flanks piedmont slopes, shallow soils and so on are being ploughed. From consideration of resource conservation, such lands used to be brought under a permanent cover. The area of such lands varies from 5 to 25% of the total surveyed.

6.2 TECHNOLOGY FOR IMPROVEMENT OF GRAZING LAND

6.2.1 An analysis shows that the present low productivity from our grazing lands is not because of any natural handicap. Our soils are fertile enough to permit establishment and maintenance of good

quality pasture lands. The native vegetation i.e. grasses, shrubs and trees are well adapted, capable of surviving through extended drought and yet efficient producers of useful, nutritious biomass during favourable interludes. The prime cause is irrational grazing practices which have lead to a depletion of the vegetative cover and attendent processes of soil deondation.

6.2.2 Possible alternatives for increasing forage production are :

1. To increase area under forages
2. To improve the genetic potential of forages
3. To have improved management practices.

6.2.3 Of the above three, the first alternative is rather less realistic since more area under forages is unlikely in view of increased pressure on land on account of alarming growth rate of human population. Hence the second and third approaches are the only possible ways by which we can expect some improvement in this regard. Of these the second alternative is likely to yield more tangible results since improvement once brought about would last longer without additional requirement of inputs etc. which are the essential features of the third approach.

6.3 SELECTION AND BREEDING OF FORAGE CROPS

6.3.1 Therefore, there is urgent need to augment our feed and fodder resources through development of improved varieties of forage crops by selection and breeding so that maximum productivity would be obtained, per unit area arid per unit time. The National Commission on Agriculture has also stressed the need for research and development efforts so as to increase forage productivity especially in the arid and semi-arid regions.

6.4 NUTRITIONAL REQUIREMENT

6.4.1 An "Ideotype" in forages would require multidisciplinary approach involving yield and quality aspects. The latter is of

specific importance as it relates to animal performance and forages have little relevance until and unless evaluated in terms of factors like intake, digestibility and utilization. Among the quality characters probably protein (thresh-hold value 7 to 8%) and dry matter digestibility (invivo or invitro) are the most important.

6.4.2 In addition to protein and digestibility, the forage should have better intake value. Leafiness has been found to be the only criterion of voluntary intake. One way of achieving this objective is to breed for leafy and palatable varieties.

6.5 HIGH DRY MATTER PRODUCTION

6.5.1 The other way for maximisation of dry matter production is to grow multicut varieties. Multicut varieties find favour with farmers because in addition to their high yielding ability, these are also capable of producing fodder at frequent intervals.

6.5.2 Quick in regeneration : It is established that the dry matter production can be increased through improvement in regeneration capacity of grasses and legumes. This is all the more important in the case of range grasses and legumes because these grow through adverse climatic conditions for a longer period than cultivated fodders. Need is, therefore, obvious to locate quick regenerating genotypes/strains. Table 1 provides the details of most commonly used varieties of forage grasses and legumes. Except a few indicated above, most of these are the result of direct selection out of the genetic variability available.

6.5.3 Breeding material now being generated at leading forage centres like IGFRI, Jhansi, HAU, Hissar, PAU, Ludhiana, IARI, New Delhi and CAZRI Jodhpur is expected to provide high yielding varieties of forages both for increased yielding and quality.

6.6 BETTER MANAGEMENT PRACTICES : Apart from breeding improved varieties of grasses and legumes, it is important to follow it up with appropriate management of pastures through reseeding improved varieties and suitable agronomic practices coupled with rota-

tional utilisation through grazing systems. Such measures when adopted will go a long way in improving our animal population.

6.6.1 Development of technology for rehabilitation of the grazing lands has been a major concern of arid zone research right from its inception. Since habitat conditions modulate the ingredients of the technology, fifty two sites, each of around 80 ha, were selected so as to cover various land types namely the rocky, semi-rocky and shallow soils, duny, deep sandy plains, saline plains and the rainfall spectrum of the region. These areas were fenced and seeded with matching species. Later, a number of replicated treatments including controlled grazing, grazing intensity, fertiliser use and water conservation measures were superimposed. In each of these treatments regular observation were made on floristic composition, forage production, grazing behaviour and body weight gains of livestock.

6.7 FINDINGS

1. Adequate protection and utilisation of grazing land at 70 per cent level, the forage yield doubles, in about 2-3 years time. Increase of forage yield in 'Poor', 'Fair' and 'Good' condition class grassland was 148.3, 91.9 and 116.3 per cent respectively.

1. (ii) Amongst the different types of fencings tried, the one with angle iron posts and barbed wire is the most efficacious and long lasting (lasting over 30 years) thus economical in long run. Present cost of such fencing is Rs.12/- per running metre. Cost per hectare is inversally proportional to size of block. Cost of such fencing in blocks of 40, 100, 200, 500 and 1000 hectares works out of about Rs.800, 576, 360, 240 and 185/- respectively.

2. Grubbing of harmful, unwanted thorny bushes and trees like, Lycium barbarum. Balanites aegyptiaca, Mimosa hamata, Acacia leucophloea etc. result in higher grass productivity. Debushing of thickets such abnexious species in Pali resulted productivity of grass species dominated by Cenchrus species 1.1, and 4.0 t/ha during first and second year respectively.

3. Provision of about 50-60 top feed trees suiting the ecosystem per hectare provides shade to grazing animals and nutritions top feed during lean periods of the year.

4. Amongst the different soil conservation measures tried on shallow soils with rolling topography, contour furrows with cross section of 929 sq. cm spaced 8-10 m aparts gave increased forage by 636 per cent (average of 10 years).

4. (ii) In extreme arid areas of Jaisalmer district, in barren gravelly soils, the mounds of contour furrows trapped shifting sands and Lesiurus sindicus (Sewan grass, king of desert grasses) established. Such lands have yielded 2.2. t/ha of forage per ha with 79 per cent contributions from Sewan grass.

4. (iii) Tranching about 300 m apart in saline soils, drained excess salinity and salt tolerant grass Sperobolus helvolus yielded 1.5 t/ha of forage.

5. Reseeding : Natural succession of high useful perennial grass species in arid regions is time consuming process. Hence reseeding of natural grass with appropriate species is the only resource. Optimum yield of 8.9, 3.6 and 4.7 t/ha from Dichanthium annulatum (heavy soils with annual precipitation above 400 mm), Cenchrus species (medium to light soils with annual precipitation above 300 mm) and Lasiurus sindicus (light soils with annual precipitation below 300 mm) has been recorded. Whereas "Poor" rangelands yield 200-500 Rs/ha under different rainfall and soil conditions.

5. (ii) Reseeding involves complete preparation of soil, removal of unwanted bushes, followed by sowings of seeds of appropriate grass species suiting the ecosystem.

Seed rate of Cenchrus species, Lasiurus sindicus and Dichanthium annulatum is 5,6 and 3 kg per hectare respectively. Higher seed rate may be needed to meet with contingencies of drought, floods etc.

Sowings in lines 75 cm apart (1-2 cm below soil), just before onset of monsoon or immediately after it is recommended. Pelleting of seeds of Lasiurus sindicus with clay, dung, sand etc. before sowings is advantageous.

One to two weedings for reseeded grasses are essential.

Rangelands with climax cover of Lasiurus sindicus where there is shortage of water should be governed by State Soil Conservation/Forest Act to prevent their deterioration.

6. Fertilisation of 'Good' rangelands with annual precipitation of below 300 mm and above 300 with 20 and 30 kg/N per hectare increased forage yield by 1155 kg/ha (31.9%) and 1389 kg/ha (34.17%) respectively.

7. Tanka (under ground water reservoir) with capacity of 200 kilo-litres is sufficient for 100 hectares of "Good" rangeland under water scarcity conditions.

8. Stocking rate of 'Excellent', 'Good', 'Fair', 'Poor' and 'Very Poor' condition class rangeland recommended is 25-30, 20, 17, 13 and 1-6 adult cattle units (A.C.U.) per 100 hectares block respectively during normal years. Under abnormal years, grazing stress has to be increased or decreased depending upon availability of forage on rangelands which is dependent upon precipitation and its distribution patterns.

9. Livestock productivity : During normal years of rainfall increase in body weight of yearling heifers (initial body weight about 80 kg) was 70 kg/animal/year. By providing concentrates as supplemental feed from December to June, the livestock productivity doubled practically resulting in early maturity.

Some data showing improvement that can be realised using above technology is given below : -

Table 2 : Carrying capacity of Rangelands under different conditions adult cattle units (A.C.U.) per 100 ha.

Particulars	Average annual rainfall 300 mm and below	Above 300 mm
1. Present carrying capacity (A.C.U.)	4-8	12-20
2. Carrying capacity after protection (A.C.U.)	8-20	24-30
3. Carrying capacity after soil conservation reseeding etc. (A.C.U.)		
4. Increased carrying capacity due to improved practices(3-1)	16-22	26-28
5. Value of increased forages(Rs.1)	8000-11000	13000-14000

6.8 FUTURE LINES OF RESEARCH-RECOMMENDATIONS

(i) Research is required for increasing the genetic potential of grasses and legumes through multidisciplinary efforts through such attributes as quality, digestibility, high dry matter yielding capacity, vigour and regenerating ability characteristics which are to be incorporated in the genotypes.

(ii) Research on better seed yielding ability of grasses need immediate attention.

(iii) Productivity and stability of different new grass strains under different agroclimatic conditions in relation to soil, rainfall, nutrient and grazing stress is to be tested.

(iv) Role of legumes in rangelands as well as in established pastures need to be examined in detail and thus studies on aspects like introduction, establishment and cultivation should be carried out. The intensive research to increase the productivity of range grasses and legumes is also necessary.

(v) Long term grazing studies on rangelands are required so that economics of primary productivity could be associated with that of secondary productivity like milk production etc.

(vi) Studies on forage preservation like hay making in good to very good rainfall years and during drought year and lean period, needs to be examined in detail (in relation to livestock production).

(vii) Studies on wind erosion and moisture conservation to control soil erosion and to improve rangelands are needed.

(viii) There is need to introduce suitable fodder tree species in range management areas and thus research on silvi-pastoral system should find priority.

Table 1 : List of Improved varieties of forage grasses and legumes

Crop	Botanical Name	Improved varieties
A. Kharif fodder		
1. Sorghum	Sorghum bicolor	JS 20, JS 263, JS 23/ $ Pusa-Chari-1, Vidisha 61-1 Nivaant HP Chari, J6, HFS 566.
2. Sudan grass	Sorghum sudanensis	SGG 59-3, HFS 478
3. Guar	Cyamopsis tetragonoloba	F-S 2777, Durgapur Safed AG 111.
4. Cowpea	Vigna unguiculata	HFC-42-1, IGFRI-S-450, 457 Russian Giant EC 4216.
5. Moth	Vigna aconitifolius	T3 and Jodhpur local
B. Perennial grasses and legumes		
Grasses	Cenchrus ciliaris	IGFRI-S-3108 , CAZRI 357, 358
	C. setigerus	CAZRI 1 and 76
	Dichenthium annulatum	IGFRI-S-495
	Lasiurus sindicus	CAZRI 318 and 319
Legumes	Stylosanthes scabra	
	Stylosanthes hamata	
	Dolichos lablab	CAZRI 144
	Clitoria ternatea	CAZRI Selection
C. Rabi fodder		
Lucerne (Alfalfa)	Medicago sativa	Sirsa-9 Avant 1 and 2
Metha	Trigonella foenum-graecum	IGFRI, S-244 TB

CHAPTER VII

7.0 PLANT PROTECTION RESEARCH

7.1 PLANT PROTECTION

7.1.1 The crops occupy relatively smaller areas in the arid and semi-arid zones than the grasslands, and attract more pests and diseases. They reduce productivity of the aridlands to a considerable extent. At the CAZRI, Jodhpur extensive work has been carried out on insects, rodent pests and their ecological management.

7.2 INSECT PESTS

7.2.1 Among insects, White grub (Holotrichia spp.), termites (Odontotermes spepe., Microtermes spp.), Katra (Amsacta spp.) Locust (Schistocerca gregaria) cause serious damage to vegetation (crops, trees and grasses) in Rajasthan, Gujarat and Haryana States.

(i) White grub : This pest occurs in monsoon season and it damages the Kharif crops (bajra, jowar, groundnut etc.). About 10-50 per cent losses have been estimated. The grubs can be controlled effectively by pre-sowing treatment of phorate 10 g @ 3.0 kg aiha or BHC 10% dust 10 kg ai/ha. The beetles do harm to host trees and can be killed by spraying on the host trees with carbaryl 50 WP @ 40 g (0.2%) or quinalphos 25 EC @ 20 ml (0.05%) per 10 litres of water.

(ii) Termites : They damage both the Kharif and the rabi crops and seedlings of the Forestry plantations. Wheat, maize and groundnut crops are highly susceptible to termite attack. 6-25 losses of wheat and maize crops have been reported. They can be checked by using aldrin 5% dust @ 1.25 kg ai/ha or BHC 2.5 kg ai/ha when applied in furrows at the time of sowing the crops.

(iii) Locust and grasshoppers : Sometimes when the Locust are in swarming phase, they become serious problem in Kharif crops in the desert region. Immense destruction of vegetation (total failure of

crops) is caused by locust swarms. Practically every kind of vegetation is eaten up by locust cultivating into famines. The estimation of losses due to grasshopper, Hieroglyphus negrolepletus is about 44.5 per cent reported on maize crop. They can be controlled effectively by, 1. collection and destruction of the yound nymphs, and 2. by dusting with BHC 10% dust @ 20-25 kg/ha.

(iv) Katra (Amsacta spp.) : This is a serious, sporadic and polyphagus pest of Kharif crops. The damage is caused by caterpillars which may be seen in large numbers in the months of July and August. In Rajasthan, 25-100% losses of pulse crops have been estimated. It can be controlled effectively by 1. Setting up of light traps or petromax following first shower of rain can destroy the moths. 2. Dusting endosulfan 4 per cent or carbaryl 5 per cent @ 1 kg ai/ha preferably in early stages of its life cycle.

7.2.2 GAPS IN RESEARCH

Considering the sweeping damages in large areas by endemic insects like Katra and white grubs, it is essential that research work should be carried out to study their behaviour, ecology and biology etc. with a major view to predict the outbreaks of these insect pests well in advance so that the farmers can prepare themselves to combat their depredation.

7.2.3 The distribution and availability of pesticides in remote areas of desert are problem partly because these commodities are hazardous. A fool-proof method should be evolved so that these chemicals are available to the farmers at the place of requirement. The training and education programme in respect of conserving the crops from insect pests should be intensified.

7.3 RODENT PESTS

7.3.1 Rodent pests have a special status in the desert ecosystem due to their role in aggravating the desertification processes particularly the soil erosion. Besides, due to their species diversity and high density of population, they inflict losses to standing

crops, grasses and other national vegetation. Their control assumes and essential component of any developmental work.

7.3.2 PEST STATUS

7.3.2.1 Food of various rodent species and their pest status has been determined. Eight species (*Meriones hurrianae*, *Tatera indica*, *Rattus meltada*, *Gerbillus gleadowi*, *Funambulus pennanti*, *Bandicota bengalensis*, *Rattus rattus* and *Mus musculus*) have been identified as most harmful to the crops and stored foodgrains in Rajasthan.

7.3.3 SPECIES COMPOSITION

7.3.3.1 Delineation of relatively abundant rodent species in the Thar desert based on ecological distribution has been established as follows :

Upto 250 mm annual rainfall	*G. gleadowi*, *M. hurrianae*
250 - 400 mm	*M. hurrianae*, *T. indica*
400 - 500 mm	*R. meltada*, *T. indica*, *G. ellioti*
Canal irrigated crop	*B. bengalensis*, *R. meltada*

7.3.4 POPULATION CYCLES IN RELATION TO ENVIRONMENTAL FACTORS

7.3.4.1 The population density of field rodents in the arid regions of Gujarat, Haryana and Rajasthan ranges upto 500 per hectare. Long-term studies have indicated that they have a broad 2-year cycle of upsurge in population. Evidences to show a relationship between population cycles, rainfall patterns and drought, are not conclusive. Changes in cropping pattern, mainly due to incoming of irrigation water through canals, has introduced a new species to the arid zone, the bandicoot, *Bandicota bengalensis* which is not only highly destructive to crops but is highly hazardous to human health as it is very susceptible to plague bacillus. It is extremely necessary to monitor their population numbers on a long-term basis.

7.3.4.2 To minimise the operation cost and to maximise the efficacy, large scale operation should be taken up during May and June (Population density and breeding rate of rodents and competition to poison-baits being minimal during these months).

Bait base : Studies conducted on 10 rodent species of economic importance have revealed that Bajra + 2% groundnut oil is the most effective bait for mixing poison for their control.

Pre-baiting : Prebaiting should be carried out before poison-baiting for 2-3 days to minimise the effect of neophobic and poison aversion behaviours of rodents.

Toxicology of rodenticides : 2% concentration of Zinc phosphide has been found to be equally effective does for the control of rodents. The acute rodenticide (RH-787) and anti-coagulants Brodifacoum and Chlorophacinone have been found effective for field rodent control.

Behaviour : Detailed studies to understand the behavioural patterns of rodents have been undertaken. For the purpose of mitigating bait shyness, poisoning with zinc phosphide should be carried out only on a single day during one operation. This poison should be used only after 3 months in the same area. If a repeat-operation is needed, both bait and the poison should be changed or fumigation of burrows with aluminium phosphide tablets (1.5 g/active burrow) should be taken up.

Bait placement : The Baits should be placed at a 10-15 m interval for an optimal coverage of bait to all the rodents.

7.3.5 On the basis of ecological distribution of various rodent species in different habitats, soil and crop types, their food; reproduction and population cycles; behavioural aspects and evaluation of various rodenticides; a number of strategies to control rodent populations in field, residential premises and godowns have been standardised. Calendar of operation for the farmers has also been formulated..

7.4 COST-WORTHINESS OF THE STANDARDISED TECHNOLOGIES

7.4.1 As a result of three years of rodent control, extension and education work in the crop fields and threshing floors in the villages, the field rodent population was reduced by 95 per cent. The losses to various vegetables, wheat and bajra crops declined by 88 per cent. The cost benefit ratio was worked out to be 1 : 900. However, in the residential premises, the rodent population was reduced by 85 per cent with a corresponding decline in losses to stored grains, vegetable etc., and the cost benefit ratio being 1 : 220.

7.5 The education and training programme had a significant impact in ensuring perception and adoption of rodent control technologies by farmers.

7.5.1 Training and Education : A number of trainings have been organised to educate the officials of the State Governments Voluntary organizations and farmers. Leaflets for farmers and training manual for rodent control operators have been prepared and have been widely circulated. Movie films on rodent control have been prepared at CAZRI and exhibited all over India through the Ministry of Information and Broadcasting under the auspices of National Programme for Rodent Past Management.

7.5.2 Zoonosis : Field rodents are carriers of a number of diseases. A highly susceptible rodent, Bandicota bengalensis, to plague which did not occur in the desert region is now colonising it alongwith the Shri Ganga and Rajasthan Canals, migrated from the Punjab. A gerbil, Tatera indica, which is the reservoir of plague bacillus, already occurs in this region. The present Lco-existence of these two rodents in the same habitat is a dangerous situation for the spread of plague. The Health Department should monitor their population increase, flea infestation and other epedimoological aspects.

7.6 GAPS IN RESEARCH

(i) Considering the species diversity long-term studies to investigate the population cycles and behaviour of desert rodents

in relation to environmental factors should be taken up by Agricultural Universities on a multi-locational basis to evolve location-specific technologies of rodent control.

(ii) Cost effectiveness of various rodent management techniques for varied ecosystems after utilising effective, cheap and safe rodent control techniques in crop fields, houses godowns and paultry farms.

(iii) The gap in research to assess the role of vertebrate predators in maintaining low density of field rodents should be filled up by Central Institutes and Agricultural Universities.

(iv) In addition to strengthening researches on chemical methods to manage the rodent pests, the research work on biological control should be undertaken.

(v) To evaluate the sex attractant pheromones and to utilize it for control measures in rodents and to utilize the process of chemical communication, through scent marking gland, in enhancing poison bait consumption, mitigation of poison aversion and bait shyness.

7.7 PLANT DISEASES

7.7.1 Black, Brown and Yellow rusts of wheat : These rusts are caused by Puccinia graminis tritici, P. recondita and P. strigormis, respectively, and are responsible for reducing the wheat grain yield. If black rust appears at an early stage of the crop, the yield may be reduced to an extent of 50%.

7.7.2 Most feasible control measure for all the three rusts is cultivation of resistant varieties such as HD 2009, Raj 911, Raj 1114, Raj 821, Sonalika. Chemical control with Vitavax and Dithane Z-78 is available but not economically feasible in these states.

7.73 Molya Disease of Wheat and Barley : It is caused by a nematode (Heterodera avenae) and is the most serious disease of Barley

in these states. This disease is responsible for 60-70% loss in these crops. Wherever soil is infested with nematode, application of D.B.C.P. (60% E.C.) @ 45 1/ha and carbofuran @ 2 kg ai/ ha can reduce the severity.

7.7.4 Downy Mildew or green ear of Bajra : This serious disease is caused by Sclerospora graminicola. A survey conducted by State Department of Agril. in 1962 and 1964 shows that this disease accounts for loss of Rs.20 million at that price index level. At present no resistant variety is available, however, few strains like BJ 104, PHB 10, 14 and BK 560 are fairly tolerant. Seed treatment with Agrosan GN (0.3%) or Apron (0.2%) is known to reduce the incidence.

7.7.5 Ergot of Bajra : it is caused by Claviceps microcephala and occurs in almost all the bajra growing areas in moderate to serve form. Seed treatment with 20% salt solution separates sclerotia from seeds as sclerotia float up in the saline water. Early sown crops have been found to escape from disease.

7.7.6 Powdery Mildew of cucurbits and fruit crops : A large number of cucurbits, fruits, legumes and cereals are severely infected with this disease which is caused by a member of Pathogens like Odium, Oidiopsis, Erysiphe, Phylactinia, Uncinula and Sphaerotheca. Important crops affected include wheat, cumin, mango, ber, watermelon, guar and other legumes. Cultivation of resistant variety is the most feasible solution. Chemical spray with wettable sulphur, karathane, calixin etc. and sulphur dusting is also recommended.

7.7.7 Smuts of sorghum : Sorghum crop suffers mainly from smuts in this area. Seed treatment with vitavax (0.2%) is recommended.

7.7.8 Bacterial Blight of Guar : It is caused by Xanthomonas cyamopsidis and is responsible for as much as 40-50% loss in arid and semi-arid areas. Seed treatment with streptocycline (0.025%) and two spray reduces the disease.

7.7.9 Tikka disease of groundnut : It is caused by Cercospora arachidicola and C. personata and is the most important disease of this crop. Copper fungicides reduce the incidence of this disease.

7.7.10 Gaps in research : Very little information is available on plant diseases in the desert region and there is an urgent need of intensifying research in this field.

7.8 RECOMMENDATIONS

7.8.1 Considering that very little attention has been paid on plant protection aspects in desert region and that there is an urgent need to minimise losses due to insect and rodent pests and diseases; it is recommended that :

(i) Agricultural Universities, Research Institutes and Health Directorates may strengthen the research work on ecology, behaviour and epidemeology of pests and diseases of desert vegetation and crops.

(ii) A surveillence Unit be created at CAZRI to regularly monitor the epidemics/outbreaks of pests and diseases with a view to develop a "Wearning System" against them.

(iii) Keeping in view the safety measures, pesticides should be readily and timely available to farmers and for this the State Departments of Agriculture should develop fool-proof marketing system.

CHAPTER VIII

8.0 SOIL AND GROUND WATER SALINITY PROBLEM

8.1 INTRODUCTION

8.1.1 Within the country, the problem of soil and ground water salinity is most extensive in the arid zone. Beset with this situation, the desert dwellers through generations of their living with problem have developed some usage of this problematic resource. Areas with extraordinary concentration of salt, like the Sambhar, Kachchh and many others are being exploited to yield over a million tonnes of common salt and the bye-products. To an extent, the saline waters are being used to raise some tolerant crops, notable amongst which is the famous 'kharchi' wheat. Likewise, some of the salt affected soils are known also to provide a moderate grazing.

8.1.2 The problem has not gone unnoticed from scientific scrutiny and as indicated below some useful information is already available. However, looking on the one hand at the magnitude of the problem and on the other at the large diversity of its nature, associated causative factors, there is scope for intensification of research in order to develop location specific strategies for their improved use. Recent scientific advances in the field made within as well as outside the country provide an insight as well as a hope that greater research effort in this direction would be ambly rewarding.

8.2 NATURE AND EXTENT OF THE PROBLEM

8.2.1 Groundwater salinity : Investigations over t years by various agencies have made the picture of groundwater quality in the region reasonably clear. These show that in arid Rajasthan (Table 1) nearly sixty per cent of the waters are highly brackish to saline (i.e. over 2.25 mmhos EC) and even the remaining waters are not entirely free from the problem. The poor quality waters occur in all the districts but the problem is most significant in Pali, Jolor, Jodhpur and Nagaur districts where ground waters exist

at easily exploitable depths. In Jhunjhunu and Sikar the water quality picture is comparatively better. The saline waters have on an average sixty to eighty per cent of the dissolved constituents made up of sodium salts, which are more harmful to the long-term productivity of soil. Therefore, the waters have not only a hazard of salinity but also that of sodicity. Some of the waters have been found to contain toxic levels of boron, fluoride and nitrate, the last mentioned constituents being important from human and animal health view point.

8.2.2 The picture is not much different in case of Haryana arid zone (Table 2). Saline to highly saline waters prevail in Hissar (including Sirsa) district. In Gurgaon and Mohindargarh districts salt concentration may not be as high, but a majority of waters have injurious levels of free soda. Therefore, summing up, a large majority of waters are problematic for one or the other reason. It is only in localised area adjoining hills that water quality is good.

Table 1 : The Distributions of water samples in different salinity ranges in arid Rajasthan.

Sl. No.	Name of the District	The No. of water sample	Percentage of samples in different EC ranges (in mmhos)					
			Below 0.75	0.75-2.25	2.25-5.00	5-10	10-15	Above 15
1.	Barmer	322	9.9	10.6	31.4	26.7	14.6	6.8
2.	Bikaner	137	1.5	27.0	36.5	21.2	10.2	3.6
3.	Churu	244	3.3	16.4	29.5	28.7	14.7	7.4
4.	Jaisalmer	295	18.9	36.6	19.7	20.3	3.8	0.7
5.	Jalore	505	9.5	27.7	29.9	19.8	10.3	2.8
6.	Jodhpur	357	7.8	37.6	26.6	16.0	7.8	4.2
7.	Nagaur	459	7.8	35.7	28.2	21.7	3.8	3.1
8.	Pali	498	12.3	33.5	20.1	17.1	9.0	8.0
9.	Sikar and Jhunjhunu	117	8.5	57.2	26.4	6.8	0.85	-

Source : Dhir, R.P. (1977) "Desertification and its control" ICAR.

Table 2 : Distribution of water samples in different salinity ranges in arid districts of Haryana

Sl. No.	Districts	No. of samples analysed	Percentage of samples in different EC ranges (in mmhos)				
			Below 2	2-4	4-8	8-15	Above 15
1.	Hissar including Sirsa	3637	17.0	24.5	47.0	9.5	2.0
2.	Bhiwani	1535	7.0	29.0	41.0	10.0	13.0
3.	Mohindergarh	1731	19.5	42.0	23.0	15.0	-
4.	Gurgaon	1567	34.0	25.0	29.0	9.0	3.0

Source : Mahchanda H.R. (1976) "Quality of groundwaters of Haryana Agric. Univ. (Abstracted).

8.2.3 In Gujarat in the vicinity of the Great and Little Ranns and then again in a narrow strip along the coast the waters are highly saline. In the rest the waters are generally brackish to moderately saline. However, even these waters are quite problematic because of high proportion of sodium salts, and at times, of free soda.

8.3 SOIL SALINITY

8.3.1 Part of the problem of soil salinity is because of irrigation with the above described poor quality waters. But besides this there are large areas of naturally salt-affected lands. In arid Rajasthan beside the playas or the natural saline depressions which are dotted all over, there are two tracts where each area occupied by saline soils is extraordinarily large. One is in the extreme north-west in the far flood-plain and the other is in the south-east in Bilara-Pali-Jolor tract. Regarding the former a fairly accurate picture is available since it falls in the commond of the Rajasthan canal, and hence has been surveyed in some detail. The information is summed up as follows :

Sub-command area	Area in hectare of	
	Highly saline	Moderately saline
Anupgarh Shakha	73,850	34,580
Suratgarh Branch	19,930	27,760
Eastern Block	37,230	-
Total	1,31,010	62,340

The above areas together constitute 24 to 40% of the command area under the Canals command.

8.3.2 Regarding the south-eastern tract, a broad picture is presented in a survey conducted by the State Department of Agriculture. A more detailed study by CAZRI in 4 lac ha of this tracts shows that salinity conditions prevail over 224800 ha or 55% of surveyed area with details as follows :

-	Total area surveyed	-	4,02,700 ha
-	Naturally saline soil	-	1,41,300 ha 35.1%
-	Relict saline soil	-	46,500 11.5%
-	Secondary salinisation due to high water table	-	37,000 9.0%

8.3.3 The above area covers only a part of the south-eastern tract and therefore when the entire tract has been surveyed, the total area of salt affected soils will be considerably higher.

8.3.4 Regarding Gujarat, the two Ranns or saline marshes cover nearly 22.5 lac hectare. Besides these, large patches of salt affected soils in the remaining part of Kachchh District and in districts of Banaskantha, Mehsana, Surendranagar and Rajkot. A survey of Surendranagar district has shown that 42,500 ha here has severe salinity problem. Gujarat has large area also of coastal saline soils and arid zone is estimated to have one lac hectare

of such lands.

In Haryana arid zone, the problem of surface soil salinity is fortunately restricted.

8.4 SPECIAL FEATURES OF ARID ZONE SALINITY PROBLEM

8.4.1 Though salt-affected soils and poor quality water are encountered in semi-arid, and even sub-humid zones of our country, the arid zone situation has a number of distinctive characteristics. More notable amongst these are : (i) The total concentration of salts is soils as well as groundwaters in arid zone condition is generally far higher than that in area with higher rainfall, (ii) Salinity is not confined to soil alone, their being larger accumulation in the substrata and groundwater. In fact salinity in the soil is only a tip of the ice berg, their being colossal amounts underneath the surface crust. Thus in these situation there is hardly any scope of finding good quality waters locally to reach down the salts; (iii) Unlike the Indo-Gangetic plains, the saline soils in arid zone except those in Rajasthan canal command have a dense sub-strata, which is not so previous to downward moving waters; (iv) for the same salt concentration, plants growing in arid zone condition environment are exposed to greater stress because of the additive effects of aridity and salinity factors.

8.5 PRESENT STATUS OF RESEARCH AND SALIENT ACHIEVEMENTS

8.5.1 Use of brackish and saline water in irrigation : The subject had been a matter of investigation at a number of institutions namely the CAZRI, CSSRI, PAU, HAU, Udaipur Univ.; Rajasthan Department of Agriculture. Presently, an All India coordinated project of the ICAR on saline water use is in operation also. Important lines in which work has gone are (1) effect of various quality waters on soil salinity, sodium absorption, permeability etc. and (2) germination, growth, yield and nutrient uptake of various crops in relation to salinity of soil and groundwater. As a result a mass of information has emerged on various

aspects. The role of clay content, nature of clay mineral of soil, besides of course, of the water quality parameters on soil characteristics has been brought out. Important crops like wheat, barley, jowar, bajra, maize, some vegetable crops and their varieties have been tested for germination and at times for growth and yield. However, most of these studies have been under controlled conditions, and often in pots. However, investigations on problems and potential of these waters in field conditions are few. A long drawn study by CAZRI has provided useful data regarding salinity alkali conditions created in soil by the use of these waters and on growth and yield of some common crops as well as their varieties. It has established also that salinity added by these waters is amenable to leaching by rainfall and also that in a cyclic management there is no progressive deterioration of soil as to make the lands unfit for recurring use. Based on the experience gained, a committee of experts had gone into the matter of water quality classification and it fixed the following criteria :

Table : Water quality ratings

Nature of the soil	Upper permissible limit of E.C. in micromhos of water for the safe use for irrigation of crops	
	Semi tolerant	Tolerant
1. Deep black soils and alluvial soils, having a clay content more than 30 per cent. Soils that are fairly to moderately well-drained.	1,500	2,000
2. Heavy-textured soils, having clay content of 20-30%. Soils that are well-drained internally and hav a good surface-drainage system.	2,000	4,000
3. Medium-textured soils, having a clay content of 10-20%. Soils that are very well-drained internally and have a good surface drainage system.	4,000	6,000
4. Light-textured soils, having a clay content of less than 10%. Soils that have excellent internal and surfaced drainage.	6,000	8,000

N.B. : For the above-proposed limits, satisfactory internal drainage and water table below 1.5 metres at the site, with the soluble sodium percentage of irrigation water below 70 per cent, are assumed.

8.5.2 Characterisation of salt-affected soils :

These problematic soils of the arid zone have received much less attention than those of the Indo-gangetic plains. Over a decade ago, the Rajasthan Department of Agriculture carried out a survey which showed a very broad distribution and characteristics of these soils in some of the districts. Of course, the picture regarding Rajasthan canal command area is far better consequent upon the efforts initially of CWPC and latter of a UNDP Project. A recent survey in Pali region of 4 lac ha by CAZRI has shown that mean profile salt concentration in majority of situations ranged from 15 to 54 mmho/cm (ECe). Further surface salinity here is only a fraction of what is present in substrata and ground water. This as well as other studies also show that in comparison to the Indo-Gangetic plain soils (which are Na/HCO_3-Cl type) the arid zone soils mostly are Na-Mg-Ca/Cl-SO_4 type. The arid zone soils have been shown to be medium or fine textured with a dense substrata or kankar underneath. The soils of the Ranns are generally very fine textured with extreme values of salt concentration. These also remain inundated for months together due to inflow of marine and inland waters.

8.5.3 On management of salt affected soils :

(i) Scientific investigations on soil reclamation have a long history in our country. However, it was only after the establishment of CSSRI in the year 1969 that a major advance could be made not only in an understanding of these soils but also in reclamation methodology. As a result a complete package of practices for improved management of the Indo-Gangetic soils has emerged and the same has gained a widespread application. Besides above, the CSSRI is doing fundamental work on soil fertility and plant mutrition, physiological basis for plant adaptation, breeding and selection of crops, grasses and trees, drainage and so on..

(ii) As regards management of salt affected soils in arid zone proper research efforts of CWPC and UNDP Project on Rajasthan Canal merit attention. Their work showed through leaching with 90 to 120 cm of canal water followed by a paddy-wheat rotation, it is possible to reclaim these for normal crops.

(iii) Studies at improved use of salt affected soils in absence of good quality irrigation waters have been few. Under its overall programme of rehabilitation of degraded pasture lands, the CAZRI has made some long duration studies on the beneficial affect of protection and reseeding on saline lands. Results show that reseeding with high perennial grass species is not very successful. However, some lower perennials like Sporobolus helvolus performs well. It has the potential to yield 1 to 1.4 tons/ha of nutritions forage. Amongst the trees, Prosopis juliflora has emerged as a key species which coppices well and has the potential to provide 10 tons of fuel wood per hectare annually.

8.5.4 Selection and breeding for salts tolerance :

Major work in the line is presently going on in the CSSRI. As of new using various criteria like yield reduction in relation to salinity, growth and yield component analysis and metabolic parameters, the Institute has screened over 300 varieties of barley, over 40 of wheat, over 200 of rice, 55 of bajra, 35 of mustard, besides those of sugarcane and sugarbeet. Besides selection, considerable work is going on also on breeding of new varieties through hybridization and metagenesis. This programme is appropriately aided by plant physiology, which through a knowledge of water relations, metabolic manifestations and nutrient balance endeavour to find a basis for tolerance to salinity of various plants types.

8.5.5 Brief account of progress made in the field in other countries : Since soil salinity is almost a global phenomenon, the subject has been a matter of study in many countries of the world for many a decade. It is neither intended, nor perhaps necessary to provide a review of all this work. The object here is merely to emphasise that a lot of impressive research and development work is going on at centres abroad, which needs to be usefully adopted to our advantage. The United States of America has made rapid strides in establishment

of salinity tolerance differences amongst a large variety of crops, water and salt movement and leaching requirement, computation of regional salt balances, use of poor quality irrigation waters and so on. The USSR and Egypt have gained valuable experience on various reclamation methods including large scale artificial drainage systems. Australia has successfully demonstrated a useful technology for raising productivity of arid salt-affected land using tolerant species and special planting techniques. Israel has made considerable headway in use of poor quality waters. Tunisia, under an internationally aided programme, has successfully concluded a project on development of location specific technologies on use of brackish and saline waters. With the increasing scarcity of good quality land and water resources, the tempo of bio-saline research has attained newer heights. We need to make extra efforts to take advantage of these advancements.

8.6 NEED FOR INTENSIFICATION OF RESEARCH FOR DEVELOPMENT OF LOCATION SPECIFIC TECHNOLOGIES

8.6.1 Soil and ground water salinity is an extensive occurrence in arid zone and therefore improved management of this problematic source merits a serious attention. Though the CSSRI has made commendable advance in the field, the technology developed for Indo-Gangetic plains can not straightway be transplanted to the arid zone. As stated earlier there are some qualitative and quantitative differences in the nature of problem in arid zone. Furthermore, in most situations, good quality waters are simply not available to bring about land improvement using this technology. The plants growing in arid zone situation are exposed to the additive effect of salinity and climate stresses.

8.6.2 Use of saline waters in irrigation have been a subject of study at CAZRI and few other institutions. Salinity conditions obtained in soil consequent upon their use have been established and some data is available on growth and yield of prevailing crops. Likewise, information is available on natural vegetation found growing in the salt-affected soils and on the improvement that can be brought about by some simple practices like protection and reseeding. However, it it felt that avenues of research are by no means exhausted.

8.6.3 There is a need for screening of the available indigenous and exotic germplasm of trees, shrubs, grasses and cultivated crops for specific conditions obtained in the arid zone. Useful genetypic variability can be further exploited for breeding more promising strains through hybridisation, polyploidy induction and mutation breeding. Possible amelioration through cultural practices, use of amendments, ponding of rain water and such other measures are worth investigating.

8.6.4 Rajasthan canal is a prized project not only for arid zone, but for the country as a whole. Some indications are available that whereas in some areas the ground water table in the command is rising fast, in others the substrata is conducive to formation of perched water table, both ultimately leading to salinity development. The situation calls for a close scientific scrutiny lest the problem takes us unaware.

8.6.5 The two Ranns of Kachchh remain a dreary waste. As early as 1965, two committees namely the FAO team on Little Rann and a Government of India team on the Great Rann had endeavoured to explore the reclamation possibilities of this area. Looking to soil and hydrological regime both the committees felt that reclamation is great problem and that field experiments are necessary before any categorical statements can be made in this regard. However, follow up action has been little and as noted by an ICAR committee on Research and Development Programmes in Kachcha District (1978), the matter brooks no further delay.

8.6.6 From the foregoing, the following emerge as important research needs :

(i) Expeditious completion of the survey of the remaining problematic area so that a precise picture of the extent and nature of the salt-affected soils in the arid zone becomes available in the near future (CAZRI, CSSRI and State Agriculture Universities).

(ii) Investigations on major types of salt-affected soils including those of the two Ranns for development of location-specific technologies based on induced leaching, change of surface configuration,

use of amendments and known salt-tolerant and salt absorbing species of vegetation and such other promising practices (CAZRI), CSSRI in collaboration with State Agriculture Universities).

(iii) A programme for screening of indigenous and exotic plant material for their tolerance under arid conditions to salinity. This should include also a systematic breeding programme using hybridisation, polyploidy, induction and mutation breeding (CSSRI, CAZRI).

(iv) Improving productivity of saline water irrigated farming system with new irrigation methods, introduction of more promising crops, induced leaching of accumulated salts (State Agriculture Universities).

(v) Close monitoring of the problem of water logging and soil salinity in canal command area notably the Rajasthan Canal command.

(vi) Though our country has also made appreciable strides in research and development work on management of soil salinity and saline waters, it shall still be a useful proposition to take advantage of the rich international experience in the field. This becomes particularly significant in view of the rate at which bio-saline research is advancing the world over.

CHAPTER IX

9.0 SURFACE AND GROUNDWATER RESOURCES

9.1 PROBLEMS AND PROSPECTS

9.1.1 Owing to the poor surface and subsurface drainage of Indian Arid Zone, the ground water in a large part of the area is highly saline and, therefore, cannot be put to any beneficial use. The hydrogeology of the arid region is also very complex and is entirely different from the remaining areas. With a view to locating freshwater aquifers and for assessing their exploitable surplus, systematic studies have been initiated by the Exploratory Tube Well Organisation (now Central Ground Water Board) since 1956-57, Rajasthan Ground Water Department since 1964-65 and by the Central Arid Zone Research Institute since 1962-63. The results of these surveys are being published by these organisations in the form of technical reports and research papers.

9.1.2 The hydrogeological investigations carried out by the Rajasthan Ground Water Department have indicated a large exploitable surplus potential of ground water in arid zone of Rajasthan. An account of this potential is given as below :

Sl. No.	District	Estimated annual recharge/annual economically mining yield	Existing annual pum-page	Surplus exploitable potential
1.	Barmer	85	40	45
2.	Bikaner	33	10	23
3.	Churu	7	3	4+89*
4.	Sriganganagar	189	75	114
5.	Jaisalmer	930	8	885+143
6.	Jalore	410	200	210
7.	Jhunjhunu	170	96	74
8.	Jodhpur	235	150	85
9.	Nagaur	250	125	125
10.	Pali	330	170	160
11.	Sikar	230	120	110
	Total	1,939	997	950/1,117

9.1.3 The work indicates that at present about 50% of the annual recharge is being tapped in the arid districts of Rajasthan leaving behind 950 mcm of surplus potential and 1,117 mcm of economic mining yield for the districts of Churu and Jaisalmer.

9.1.4 Out of the total area of the arid zone of Rajasthan, 40% of the area contains potable water, whereas in the rest of the area, the quality is saline to highly saline.

9.1.5 A brief description in relation to the water bearing formations of the main lithological units is summarised below. The details of the geology area given elsewhere in this publication.

9.1.6 The rocks of the Aravalli system comprise gneisses, schists, phyllites, slates and quartzites, and occur in a part of the Sikar and Nagaur districts. These rocks are hard and crystalline. Ground water in these rocks moves through joints, fractures, foliation planes and weathered zones wells dug to tap these formations yield a poor discharge, ranging from 30 to 60 cubic metres per day.

9.1.7 The Raialo series comprises crystalline limestones with dolomites. Ground water occurs in joints, fissures and cavities which yield water upto 30 cubm per hour.

9.1.8 The rocks of the Delhi system include mica schists, phyllites, calc gneisses and schists and quartzites. Ground water in these rocks also occurs and moves through the joints fractures, foliation planes and weathered zones. Wells tapping these formations yield discharges ranging from 40 to 80 cubic metres per day. The Ajabagarhs in the Punjab and in Haryana are fairly good as water carriers and the wells in them yield discharges ranging from 3.6 to 10 cubic metres per hour.

9.1.9 The rocks of Jalore, Siwana, and Erinpura granites, and Malani rhyolites, which are known as the igneous suite of intrusive rocks are very poor aquifers. These rocks yield very limited supplies of ground water through joints, fractures and weatherd zones.

9.1.10 The sandstones and limestones of Vindhyan age, locally termed the Jodhpur, Bilara and Nagaur group of rocks form good acquifers in these areas. Well tapping these formations are capable of yielding good discharges ranging from 50 to 100 cubic metres per hour.

9.1.11 The Lathi sandstone of lower Jurassic age of Jaisalmer is a good aquifer of fresh water. It is capable of yielding high discharge to wells ranging from 100 to 175 cubic metres per hour.

9.1.12 In Kutch, the rocks of Patcham and Chari series comprises calcarious shales and limestone and the quality of water is, therefore, saline. The rocks of the katrol series are impervious, yielding only a meagre supply of salty water. The Umis series were deposited only under fiuviatile and esturine conditions. The marine formation of the series yields only saline water, and, hence, there is no development of ground water in the fossiliferous sediment of the series. Ground water in the Bhuj sandstone occurs under both confined and unconfined conditions. The static water level in the dug wells ranges from 2 to 30.5 m below ground level (b.g.l.) and that in the dug-cum-bore wells and the tube wells tapping the confined aquifers from 3.4 to 31.4m. b.g.l. Ground water to the tune of over 9,000 to 26,000 million litres has been made available for irrigation in the lower and upper Bhuj series respectively in Kutch. The tube-wells located well within the Bhuj sandstones yield about 48.78 cubic metres of water per hour. The quality of water is generally good. In the Deccan traps, in Kutch and in Kathiawar, ground water occurs along joints, fractures and secondary partings, which are generally limited in depth up to 50 m. The static water level in the dug wells ranges from 4 to 12 m. The yield of wells tapping these formations is moderate.

9.1.13 The semi consolidated sandstones of the Eocene age and the alluvial formations of the Quaternery system occupy the major part of the area in western Rajasthan and form good aquifers of potable to brackish water. Wells tapping these formations are capable of yielding good supplies, ranging from 40 to 80 cubic metres per hour.

9.1.14 The Central Ground Water Board (erstwhile Exploratory Tube wells Organisation) started the drilling operations for exploring the possibilities of exploiting the ground water resources in Western Rajasthan as early as 1956-57 wherein 10 exploratory drilling sites were completed under 1st phase followed by the second phase of 15 sites during 1959-61. Subsequently, the following programmes were completed; 10 exploratory wells around Chandan (Jaisalmer district) during 1961-62; 12 exploratory wells in RCP area and 4 wells in C.M.F. area, Suratgarh (Ganganagar and Bikaner districts) during 1960-62; 17 exploratory wells in Rajasthan during 1962-63 and 70 exploratory sites in Rajasthan during 1962-63. Also under deposit well programme 3 wells 6 Observation holes (DH) in Singhana area (Jhunjhunu district), 3 wells and 6 DH in Jodhpur area and 2 wells 4 DH in Choumiva area (Jhunjhunu

district) in 1962 for Khatri Copper Project and 200 production wells programme during 1964-67 period due to drought in western Rajasthan.

9.1.15 The ground water assessment studies have been carried out in Western Rajasthan during the three different phases under the UNDP Project from 1967 to 1978. Under phase 1 (1967-71) 60000 sq.km. area was covered out of which 4711 sq.km. area was taken up for detailed investigation fall ng in the administrative district boundaries of Jalore, Jaisalmer, Barmer and Jodhpur and 95 bore holes of various types were drilled.

9.1.16 The UNDP phase-III (1974-78) covered only part of the Ganganagar district in Rajasthan under the Ghaggar Project and 55 boreholes were drilled. The static ground water reserves calculated frotne 928 sq.km. in Ghaggar flood plain comes out to 4268.8 mcm. Estimated exploitable resources area of the order of 2,537.27 mcm in the entire fresh water belt of about 12,772 km^2 area.

9.2 WATER RESOURCES PROBLEMS AND PROSPECTS IN RAJASTHAN

On the basis of the considerations of surface and underground drainage conditions and their characteristics the water resources of Rajasthan can be best described after classifying it into following zones.

9.2.1 DEFINED INTEGRATED DRAINAGE SYSTEM

9.2.1.1 Luni : This zone is covered by the Luni river system and its tributaries and occupise 34,866 sq.km. area (nearly 10.6% of the region as a whole). The flow in the river system is in direct response to precipitation and the flow is dependent upon the intensity of the rainfall which is highly variable. In average rainfall years nearly 254 mcm of water goes out of the basin unutilised. The zone has nearly 79 medium and minor dams. Besides these, practically each village has one village tank (Nadi) the water of which is utilized for human and livestock drinking for periods varying from 2-12 months. The hydrological problems in this zone inter alia are :

a) Major rock formations are granite rhyolites underlying shellow soil and watered mantle varying in magnitudefrom less than a metre to nearly 25 metres. Consequently the storage capacity of aquifer is poor, groundwater is mineralised, construction of dams and canals have developed salinity and water logging.

b) Since the geology of terrain consists of igneous rocks, the surface water resources are also not free from hazards in as much as 1) the stored water gradually turns saline 2) because of weathered nature of rock formation, the surface water carry too much of suspended load and thus reduce the storage capacity of reservoirs 3) the stored water is subject to various pollution, evaporation and seepage losses.

9.2.1.2 Sahibi river :

(i) The river Shahibi originates from the Aravalli hills in the district of Jaipur in Rajasthan and flows through Rajasthan for a length of 145 km before it enters into Haryana. The basin of river within Rajasthan lies between N latitude $27^{o}15'$ and $29^{o}15'$ and E longitudes $75^{o}45'$ and $77^{o}15'$ and dovers and area about 6216 sq.km in parts of Jaipur, Sikar and Alwar districts. Gauge and discharge data of this river is being observed at Sodawas and Ajerka. The observed peak discharge at Sodawas during the period 1965-77 varied between 1204 to 42853 cesscs. Similarly at Ajerka it varied between 3534 to 16044 cusscs.

(ii) Ground water is encountered in bed rock aquifers consisting of quartzites, schists, slates, phyllites marble, granite and amphibolites and in alluvial and aeolian aquifers consisting of gravel sand and silt etc. The depth of water varies from 2 to 35 m in bed rock - aquifer and near surface to 23 m in alluvial aquifer. The saturated thickness of bed rock aquifer ranges from 1 to 8 m, whereas it varies from 30 to 70 m for alluvial aquifer. The yield of the wells in the basement aquifer 30,000 to 1,00,000 lpd and wells can be sustained draft for 2 to 4 hrs. whereas the yield from sedimentary aquifer varies from 470 to 984 lpm for a drawdown of 2.5 to 7 m. The specific capacity of alluvial aquifer ranges from 70 to 381 lpm/metre and transmissivity from 137 to 3141 m^2/day. The permeability varies from 5.6 to 103 m/day. The storage coefficient varies from 0.146 to 0.0016.

(iii) The infiltration rate varies from 2.54-18.40 m^3 per day per m^2. In general total salt consent in shallow aquifer varies from 320 to 1280 ppm, whereas in the deeper aquifers it varies between 294-566 ppm. The concentration of chloride does not exceed 250 ppm and hardness as $CaCO_3$ varies between 13 to 485 ppm.

(iv) Investigation by Central Ground Water Board (CGWB) indicates that due to presence of poorly permeable formations, trick clay beds at shallow depth, shallow water level and continues rising trend of water level preclude the possibilities of increasing ground water within the basin by artificial means. It should be further concluded that the available subsurface storage for accommodating the flood water is inadequate to make a significant dent on the flood. However, it may be possible to increase to a minor extent the amount of intake of flood water through seapage by depleting the water table by about 1.4 m in fresh water areas. However, this exercise would require additional data collection and detailed field investigations.

(v) To control this flood water, the Central Water Commission (CWC) in collaboration with the stage Departments has already prepared a master plan and the same is being implemented also.

9.2.2 Canal Irrigated Zone :

9.2.2.1 This zone lies in the north western part of the area and occupies nearly 11% of the arid zone. The Rajasthan canal project, one of the largest canal systems of the world, is our gigantic stride to harness natural resources, for the well being of the people. It gives us the potential to transform the economy not only of the Rajasthan but to a good measure also of the country as a whole. It aims to irrigate 1.14 million ha of our most desiccated lands. For administrative convenience the project works have been subdivided into two stages. The stage I comprises 204 km of feeder canal, 189 km of main canal, about 3000 km long distribution system. All these works have almost been completed and irrigation provided to 3,21,000 ha out of the targeted 5,36,000 ha. The stage II works are in full swing and as of March, 1981, 106 km length out of total 256 km main canal has been completed. 125 km of distribution system has been lined.

9.2.2.2 In order to accelerate the realisation of benefits from this prestigeous project there is a command area development project. It provides necessary physical works like land-levelling and shaping, lining of water courses, agriculture supporting services etc. Department of Agriculture of Rajasthan has a sizeable establishment to demonstrate and propagate improved soil and water management technology.

9.2.2.3 Investigating already completed or in progress for sustained LAND productivity :

As part of the feasibility study, the CWC (then CW & PC) had carried out an exploratory soil survey. Subsequently, a reconnaissance soil survey was undertaken for the entire gross command area as part of a UNDP Programme. This survey also assessed the lands for their irrigability. It showed that soil salinity and perched water table formation due to presence of horizons of low permeability in solum was a problem in 78 thousand ha particularly in the Anupgarh Shakha. Larger areas of stage I further south and of stage II were found to be very light textured and thus prone to severe deep percolation losses and wind arosion. Nearly 113 thousand hectare are seen to have thick 'kankar' or gypseous strate the permeability of which was of doubtful nature. Though precise information is not available, it appears that some cells exist both in the Irrigation Department and Agriculture Department to monitor the water table built up problem in the region.

9.2.2.4 The problem of water table rise : **The UNDP-FAO project report** of the year 1970 shows that the water table in the Gang command area is rising at the rate of 0.3 m per year. Further, based on the Hoon's data of the year 1952 and their own observations during April-May 1970 this study shows that as regards Anupgarh Shakka command the water table was rising at an average rate of 1.52 m per year, whereas in the Eastern Block the rate was 1.22 m. CAZRI based on the above data as on that of the Rajasthan Irrigation Department for the period from 1962-1975, has computed the water table rise for different zones of the command area. It has further shown that at the present rate problem of water table will get critical in a major part of the common area shown below in less than 50 to 100 year period.

1.	Bhakra canal	1710 sq.km.
2.	Gang canal	2930 "
3.	Ghaggar Flood water irrigation	4820 "
4.	Rajasthan canal	1300 "

9.2.2.5 As mentioned above, 113 thousand hectare of land in phase II are underlain by a kankar or gypseous pan. Some indications are already available that this substrate has the potential of restriking drainage and creating water logging problem in a very short span of time. It is learnt that a committee of the State Government with assistance of GSI has also gone into the issue.

9.2.2.6 Summing up it can be said that soil and substrate conditions in the Rajasthan canal command area rather adverse than those encountered in the Gang Bhakra canal command. It is very important that scientifically sound investigations are taken up early lest the problem takes us unawares.

9.2.2.7 It is of paramount importance to know the subsurface condition i.e. location, magnitude and aerial extent of kankar pan, gypsum and salt beds, clay formation like Fuller's earth, Bentonite. This will help in planning the lay out of secondary cannals and field channels and also to construct inverted injunction wells so that the seapage water percolates below these horizons. This can be best achieved with the help of Geophysical survey on close grid system followed by a few core drilling and pump testing to ascertain the hydrological proporation of the subsurface formations.

9.2.2.8 Zoonosis : Rodents are carriers of a number of diseases. But these are noticed only when outbreaks of diseases like plague occur. Such latent situation is being created in the Rajasthan canal area also. A detailed ecological survey of the rodent populations carried out by the CAZRI has revealed that a field rodent (Bandicota bengalensis) has migrated into Rajasthan alongwith Sriganganagar and Rajasthan canal and has colonised the field bunds at alongwith the banks of the canals. It is freely intermingling with the Indian gerbil Tatera indica a vector which is wide spread in the desert region. Whereas T. indica is

highly resistant to the plague bacillus, Bandicots bengalensis is highly susceptible. The coexistent of these two species of field rodents in close proximity can cause into a outbreak of the plague among human beings. It is probably the law infestation of fleas (Xenopsylla) on the rodents, which transfer the plague bacillus from one species to other which is acting as a break to the spread of plague. It is, therefore, urgent that the incidence of flea infestation on the field rodents in the canal common area is regularly monitored and epidemological studies on the rodents are carried out in detail.

9.2.2.9 In the irrigated field of northern Rajasthan the prevalence of viral tever is very high. The Health Deptt. should take up studies to correlate the incidents of these diseases with field rodents which are their carriers. This will possibly result into a complete eradication of the diseases from the region. So far, no work has been done in this field.

9.2.2.10 The problem of new weeds :

(i) The incoming irrigation water from non-desert areas to desert areas brings with it new weeds. The water hyacinth has already become a problem in certain parts of the Rajasthan canal alongwith water. A large number of weeds which do not occur in the desert have now weeds have been transported by the Canal waters. The problem of introduction of new weeds need a detailed study.

(ii) The water hyacinth and Salvinia has already become a menace in some parts of the Rajasthan canal and is on the verge of clogging some of the tributaries.

9.2.3 Zone III occupied by sandy plains, dunes and eroded rocky plains :

9.2.3.1 Such zones occupy the remaining 78.4% where the inhabitants are mainly dependent on village (Nadis) tanks or 'tankas' for their drinking water requirement. Some of the more important problems in this zone are :

(i) The viallage tanks have surface water for only 2-6 months a year.

(ii) The tanks get silted up in 8-10 years and hence need dredging operation every year, or at least once in three years.

(iii) The ground water in this area is moderately very deep ranging upto 100 m.

(iv) The ground water bodies here do not occur as homogeneous and continuous formation but are isolated basins having no hydraulic or hydrogeologic continuity.

(v) About 65% of the aquifer have salts contents of over 3200 ppm.

(vi) Under specific subsurface conditions in dune area, perched water bodies develop having potable water although with restricted area extent and limited storage capacity.

(vii) Some of the ground water whether from deep seated aquifer or perched water bodies contain toxic elements like boron, fluoride and nitrates, etc.

(viii) In the characteristic presence of calcium carbonate pan below sandy alluvial cover, the runoff component is low from the meagre rainfall and is unable to recharge the aquifer except during abnormal rainfall years.

(ix) The Churu system of conservation of surface water has been functioning in a traditional manner providing enough drinking water to the family but there is scope for scientific improvement of the storage based on cost-benefit analysis.

9.2.3.2 Lathi Basin (fossil) water

(a) Lathi formations are an important constituent of zone III and have an areal extent of about 7500 sq.km., of which 3272 sq.km. area has fresh ground water, having T.D.S. less than 2000 ppm. The static water level varies between 24 to 53 m.b.g.l. The coefficient of transmissibility ranges from about 21500 to 225000 lit. per day per metre. In a large part of Lathi formation the coefficient of

transmissibility is more than 110,000 lit. per day per metre. Considerable quantity of water can be obtained for domestic, livestock and agriculture use. The wells having a depth of 150 m have high yielding capacity i.e. 300 cum/hr. To irrigate 500 sq.km. of area about 40 such wells will be required. To recharge to the Lathi aquifer was thought to be negligible hence the recommended ground water exploitation was a mining exercise. However, the reappraisal by the Central Ground Water Board, Jodhpur have revealed that the Lathis received an annual recharge of about 27.4 mcm and for a potential draft (based on optimum utilization of existing wells of 5 cmc) leaves about 22.4 mcm of surplus ground water sufficient to sustain pumping by additional 60 tube wells having yield of 100 m3/hr each. After 200 years of pumpage the static water level would vary between 69 to 78 m.b.g.l. The poorest quality from any individual well will be less than 2000 ppm D.T.S. But some wells would produce water containing 700 ppm. The initial composite TDS content of water would be about 1000 ppm. Even after 200 years pumping the composite water would be still in usable quality limits.

(b) The area has already more than 35 wells. But most of the wells are lying unused or are being used occasionally except 13 which are under regular operation for drinking water supply, bullmother form or the agricultural demonstration farms.

(c) The following are the approximate cost estimates for the ground water in the Lathi basin area.

(a)	Diesel operated tubewells including depreciation and interest	Rs.32.32 per acre inch.
(b)	Electric operated tube well with depreciation and interest	Rs.17.03 per acre inch.
(c)	Electric operated tube well with depreciation only	Rs.13.39 per acre inch.
(d)	Electric operated tube well without depreciation and interest	Rs.11.30 per acre inch.

9.3 THE "KHADIN"-A UNIQUE WATER HARVESTING SYSTEM IN THE DESERT

9.3.1 'Khadin' is a novel system of raising crops employing water harvesting technique in the most desertic part of Rajasthan. It is

reported to have been developed by Paliwal Brahmins in Jaisalmer in the 15th century. Here the local ingenuity has taken advantage of the numerous rocky, gravelly catchments and divered water to develop cases of productive lands. There is even a large garden, bedecked in the otherwise dreary setting. The system is so efficient that a 50 to 60 mm rain spell is sufficient to charge the Khadin into raising a successful Bajra crop. If the rainfall is higher or late in the season the Khadin farmer does not mind losing a bajra crop for a bumper rabi crop. A number of Khadins have a stepped sequence and in abnormally wet years, the abundent water is used for charging the lower part of the sequence.

9.3.2 A study by CAZRI on structure and functioning of the system shows that runoff to runoff area ratio of the Khadin varies from 1:12 to 1:15.

9.3.3 The runoff water contains some dissolved salts. Normally with a ponding system in course of years a situation should arise, when the soils get highly saline. However, it is remarkable to state that in majority of situation this has not happened. The prime reason for this is the care taken in it of a flushing mechanism when the salts get washed down stream.

9.3.4 Seeing the success of the system, the state Government has taken up development of Khadin as part of its public welfare programmes and good progress has been made in this regard.

Table : Characterisation of Khadins

Sl. No.	Name of Khadins	A Area of catchment (sq.km.)	(a) Area of Khadin (sq.km)	(a) A	Drainage density (km/sq.km.)	Average slops (%)
1	2	3	4	5	6	7
1.	Rupsi I	52.8	0.33	0.01	**2.04**	0.8
2.	Rupsi II	5.3	0.14	0.03	**1.83**	0.95
3.	Bhadesar	6.38	0.56	0.09	**1.41**	0.58

	Max.cap. of khadin m.cum	Infiltration rate (cm/hr)	Depth of khadin (m)	Rainfall (mm)	Runoff mcum
1. Rupsi I	0.22	3.0	1.42	217	5.43
2. Rupsi II	0.10	4.8	1.50	217	0.55
3. Bhadesar	0.21	3.0	0.55	217	0.66

9.4 ZONE WEST OF JAISALMER WHERE SUBSURFACE OR BURIED CHANNELS OF THE MIGHTY VEDIC SARASWATI EXIST

9.4.1 This zone lying as a strip along the international border with Pakistan is a dune covered area. The problem in the area is that for want of proper water resources in many border areas, water is either transported or stored in tankas constructed in local depressions to collect rain water. Under such conditions exploration of ground water resource is of prime importance.

9.4.2 The Saraswati river, which is quoted in the ancient Indian scriptures as a mighty one, has been identified by many scholars with the present dry bed of the Ghaggar in Haryana and Rajasthan and with the Raini, Wahinda and Nara streams of Pakistan. Although many of them have acknowledged the shifting behaviour and gradual drying of the river that originated in the Siwalik hills of the Himalayas, none has described the courses of this river systematically from its source to estuary. Recent studies by the CAZRI scientists reveal that formarly the Saraswati had its courses through the desert of Rajasthan. The oldest course was roughly through the present sites of Nohar, Surjanasar, Samrau, Pachpadra and then along the present lower course of the Luni. This was followed by another major course through Siras, Lunkaransar, Bikaner and Pachpadra. The Luni was, therefore, a tributary to the Saraswati and the Saraswati system of rivers contributed much in the alluviation of the region. This was followed by some other major shiftings in the courses of the river whereby it severed its link with the Luni and occupied the different stream segments now known as the dry beds of the Ghaggar between Nohar and Anupagarh. South of Anupgarh the river used to flow through Sakhi, Islamgarh (in Pakistan), Dharmi Khu, Ghantial, Shahgarh, Babuwali (all in Jaisalmer district of India), Rajar and Mihal Mungra (both in Pakistan) and then through the present lower course of the Nara. This was the course of the Saraswati from the Himalayas to the Rann of Kutch after the river delinked itself from the Luni. Subsequently a number of westward shifts occurred from this course and the river identified itself with the present Raini, Wahinda and Hakra-Nara in Pakistan. Finally the river ceased to flow even through these courses and met the Sutlej to the west of Ahmedpur East (in Pakistan).

9.4.3 While one of the main reasons for the sustinance of the river was more wetter climate in the past, the other was the Sutlej's contribution of water to it in the Sub-Himalayan plains. As the climate became more dry and the Sutlej shifted its course away from the Saraswati the latter become more and more erratic in flow and then became dry. However, since the dry beds of the Ghaggar and the buried course of the Saraswati in Jaisalmer district are of sub-recent period, with headwater connections in the Himalayas, the above course can still yield subsurface water. The few dug-wells at Dharmi Khu and Ghantial do not dry up even in the extremely dry summer months, inspite of severe cattle and human stress, suggesting continuous recharge of water from the upstream side in the Himalayas.

9.4.4 The cause of shifting and designation of the erstwhile mighty Saraswati channels was geomorphic evolution in the catchment area. If this cause is removed or ameliorated more water will flow through the dry beds of the Saraswati in the Rajasthan desert.

9.5 PROSPECTS OF ARTIFICIAL RECHARGE IN ARID ZONE

9.5.1 Preliminary studies at the CAZRI have indicated adequate surplus water from various sources which are at present not being utilised.

9.5.2 Sources of surplus water : The principal sources of SURPLUS WATER INTERALIA are 1) Rain water-studies at CAZRI have indicated that in Western Rajasthan, about 19,000 mcm of rain water remain unutilised every year. There are also possibilities of receiving as high as 22,000 mcm surplus rain water every fifth year. 2) rising ground water in irrigated areas.

9.5.3 These surpluses of water can be best stored in aquifera for utilisation during the period of drought and artificial methods of recharging constitute an excellent method to achieve this objective. Nearly 28145 sq.km. of this region is capable to receive the recharge. So far no studies have been undertaken to standardise the techniques for adoption of such methods, by any organisation. As such the investigations on the applicability of artificial recharging methods for different terrain characteristics in different rainfall zones including economics needs to be undertaken.

9.5.4 Adopting artificial recharge method, is one of the best method to put back the surplus water into the Earth's crust and use it when required. It will not only provide much needed water in times of drought but will also enhance the life of the well by 15-20 years.

9.5.5 Based on the distribution of surplus water sources the aquifers it has been calculated that the surplus rainfall is best source of recharge for the aquifers in the Jhunjhunu Sikar, eastern part of Nagaur, Jodhpur, Pali, Jalore and Sikar districts.

9.5.6 River flood waters seem to be the best source of recharge to the aquifers only along the courses of river Luni, Jawai upto the point they meet each other. Above all "conjunctive utilisation" of surface water and ground water seem to be the most suitable method under the existing "socio-economic" conditions of the region.

9.5.7 The surplus round water developed under canal irrigation is the best source with recharging aquifers for Sriganganagar, Bikaner and Jodhpur districts. By doing so, we not only benefit the deficit zones but also control the problem of water table rise and associated water logging and salinity problems of such areas.

9.5.8 Although various organisations are engaged in a limited sense to study one or the other above mentioned parameters independently, none of the organisations have viewed the water resources as one entity and then to consider the various management aspects for the conjunctive utilisation of the scares water resources on both short and long term basis.

9.6 FUTURE RESEARCH NEEDS

9.6.1 Surface water Resources : Measures for improved conservation of water in village tanks. In good rainfall years more than 80% of the village tanks get filled with water. However due to high seepage and evaporation losses, the water in these tanks last only for 1-2 months. Similar problems hold good for Haryana and Gujarat. Intensive research is therefore required to be focussed towards :

a) minimising evaporation losses and testing different evaporation control measures.

b) reducing seepage losses.

c) monitoring of sediment deposition in reservoirs and streams through Landsat imageries.

d) control of silt/sediments through suitable mechanism and design.

e) prevention of water pollution in tanks by animals through proper designing of accessibility to the latter.

f) develop a suitable structure for disposal of surplus inflow to avoid serious damage to the village ponds.

ii) a) In the Rajasthan canal area, the soil and substrata conditions are rather adverse than those encountered in the Gang-Bhakra canal command area. It is important therefore that scientifically sound investigations are taken up early lest the problems of water logging and salinity may not take us unawares. To this end it is of paramount importance to know the subsurface conditions i.e. location, magnitude and serial extent of Kankar pan, gypsum and salt beds, clay formation like Fuller's earth and Pentonite. For this purpose geophysical survey on close grid system followed by a few core drillings and pump testing to ascertain the hydrological properties of sub-surface formations require to be undertaken.

b) The introduction of irrigation waters has coincided with the appearance of field rodents (Bandicota bengalensis) which is considered a reservoir of the deadly bacillus responsible for plague epidomic. Ecological surveys are necessary to assess the magnitude of their incidence and their life cycle.

c) Weeds alien to the desert have also found their way in the irrigation waters and systematic floristic appraisal are urgently called for because such plants as water hyacinth, Arundo donax and Typha anqustata are choking the canals already and measures for their control require investigation.

iii) Delineation and mapping of khadins and water flows in Jaisalmer, Barmer, Nagaur, Churu, and Sikar districts require to be taken up. Detailed studies are necessary to sea where the water goes.

iv) In the arid region of Bhuj in Kutch district and Banaskantha district in Gujarat, research is required to develop a technology for evolving suitable design for soil and water conservation, design of small size ponds for livestock drinking and efficient method of water harvesting suitable for arid region of Gujarat.

v) Now drainage areas if any recharge is possible from drainage areas.

9.6.2 Ground Water

(i) Characterisation of aquifer for properties like porosity permeability storage and transmissibility : natural recharge employing **ratio-isotopes.**

(ii) Geophysical surveys to ascertain aerial extent and magnitude of the aquters.

(iii) Pump testing to ascertain various hydrological properties of the aquifers.

(iv) Studies on the dynamics of groundwater movement in canal irrigated areas and on hard rock and sandy terrain in order to evolve a drainage system.

(v) Joint exploration by CAZRI and Central Ground Water Board for locating subsurface water resources in extreme western scrip where prior course of mighty Vedic Saraswati has been fully reconstructed.

(vi) Delineation and mapping of buried suballuvial ridge intruding in southwest Haryana for possible breaking at places.

9.6.3 Holistic approach to surface and groundwater investigation :

(i) Water balance studies of index catchment or mini-catchments.

(ii) Studies on the applicability of artificial recharge methods for different terrain characteristics under various rainfall zones landuse practices, socio-economic conditions including evaluation of the economics of such methods.

9.7 WATER RESOURCES PROBLEMS AND PROSPECTS IN SOUTH AND SOUTHWEST HARYANA

Like Rajasthan, the rainfall is deficient in the south and south west parts of Haryana adjoining Rajasthan and hence the water resources are scarce in this tract.

9.7.1 Geology : In Gurgaon, Rohtak, Mahendragarh and Bhiwani districts hard rocks of the Delhi system (precambrian in age) occur exposed. Regarding the bacement topography an intruded granite massif is present in the Ellenabad - Sirsa tract while in Mahendragarh district the post Delhi intrusives - pegmatites quartz, granites etc. and the rocks of Ajaibgarh, Kushalgarh and Alwar series form the basement while the recent to subrecent alluvium and wind blown sands overlie it.

9.7.2 Aquifer conditions : In the south western parts of the state where huge wind borne sediment have accumulated over the alluvium the possibility of earlier shallow aquifers becoming deeper is quite evident. The discharge of the tube well decreases in the south western part of Haryana compared with the north eastern parts of the state. In most of the long duration pump tests at different exploratory tube well it is observed that the values of storage coefficient are low (4.8×10^4) in the southwest parts. The value of transmissibility is also low (6.7×10^4 USGPD/ft) in the southern and western parts.

9.7.3 Hydraulic gradisnt : The ground water generally follows the topography of the area. The hydraulic gradient in the Sahibi river basin is from south to north and it ranges from 5 to 15 ft./mile. In the Krishnawati Basin in Mahendragarh district, the ground water flow is from south west towards north east and north north-east.

9.7.4 Ground water Table : In Hissar district the subsurface water is quite close in Ghaggar river bet but away from it the depth increases from 60 to 100 feet. In Mahendragarh district generally, it varies from 60-100 feet but in Krishnawati and Sahibi basins it is quite little. It has been thought by many investigators (Auden 1950) Uppal, 1953) that there is a suspected buried ridge or high density alluvium under Punjab plains. The introding ridge of impervious material which is lying concealed under Ghaggar - Yamuna alluvium acts as an obstacle

to the flow of subterranean water from the Siwalik intake area towards the south west dry regions of Haryana. It is an obstruction to use of water in south west inhibiting the accessibility to fresh water for drinking and irrigation purpose.

9.7.5 Seasonal fluctuation of water : Observations on the seasonal fluctuation of water table in the south and southwest areas of Haryana show that the average seasonal water table rise in Sahibi basin in Mahendragarh is about 4.3 feet whereas that in Krishna/Saraswati river basin about 3 ft which is also in Mahendragarh.

9.7.6 Quality of Ground water : (a) In the extreme eastern part of Narnaul in Mahendragarh district, pockets of saline ground water occur. In the remaining areas of Mahendragarh, the shallow aquifers have fresh water.

(b) Haryana State Minor Irrigation Corporation has divided Haryana into four assessment zones based on the quality of ground water, the depth of water table and thickness of water holding strata. Ground water quality is a serious problem in tehsils of Dabwali, north eastern and southeastern parts of Sirsa, northern part of Hansi, southern part, northern part of Bawani, Kera, Bhiwani, north Loharu, south western part of Rohtak, and southeastern tip of Hansi.

9.7.7 Recommendations on groundwater improvement

(i) breaking at places of the sub-alluvial ridge.

(ii) construction of earthan embankments round fields so that available rain water may percolate.

(iii) making provision for collecting the flood water of seasonal streams by constructing reservoirs, so that the water may ultimately sink into the ground.

(iv) increasing the intensity of canal irrigation in rainfed areas.

9.8 WATER RESOURCES - PROBLEMS AND PROSPECTS IN GUJARAT

9.8.1 General

9.8.1.1 Substantial areas of Gujarat state periodically experiences droughts leading to considerable loss in agricultural production.

Ecological deterioration because of denudation of forests and excessive grazing has led to soil erosion. 41 taluks in 10 districts of Gujarat badly experience drought. Banaskantha, Kutch and some parts of Mahesana and Rajkot are frequently hit by drought every year. A large part of this region suffers from poor soil, undulating terrain and undependable rainfall. Irrigation facilities are extremely limited in this region. Soil erosion by wind takes place continuously in this part on an intensive scale. Large areas of the State fall within the arid or semi-arid zone. According to the irrigation commission, 58 talukas of the State covering 35% of the total area are drought prone.

9.8.1.2 Recurrent droughts in large parts of the State have been one of the most distressing features of the State economy. Apart from the loss of production and the depletion of cattle wealth, the impact of drought is shattering on the agricultural economy. Acute shortage of drinking water and fodder further aggravate the problem.

9.8.1.3 The problem of development of the desert areas in Kutch and Banaskantha possess an even greater challenge and calls for substantially large magnitudes of investment.

9.8.1.4 The process of reclamation of Khar lands for cultivation is slow and costly. The over exploitation of ground water resources for irrigation along certain parts of the coastal areas has caused the problem as salinity ingress which is assuming serious proportion.

9.8.1.5 The problem of drinking water is also acute in coastal areas. There are prospects of development in several directions.

9.8.2 Soil Water Conservation

9.8.2.1 Drought prone areas programme aims at mitigation of the effects of drought through integrated area development in agricultural and allied sectors of the rural economy. The strategy is to improve the economy of these areas through a package of infrastructural and on-farm development activities with the objective of optimum utilisation of land, water, human and livestock resources of the selected area. The main thrust of the efforts is in the direction of restoration of a proper ecological

balance in the areas. The programme include (1) development and management of water resources (2) soil and moisture conservation measures etc.

9.8.2.2 The programme is in operation in 10 districts inclusive of 3 desert districts of Kutch, Banaskantha and Mehsana. An outlay of Rs.362.10 lakhs has been kept in sixth plan for soil and water conservation and farm ponds.

9.8.2.3 The soil conservation works namely contour bunding, terracing, nala plugging etc. were carried out in small catchments. New management systems on water shed basin has been introduced from the year 1976-77. In north Gujarat, the soil is sandy and hence the work of land levelling, land terracing, pasture development, construction of farm ponds and afforestation has been initiated. The works is in progress in arid part of Gujarat upto March 1982 (Table 1) under soil and water conservation programme. On waterhed basis, the works like contour bunding, terracing guley plugging, land levelling, Kyari making, water harvesting structures like farm ponds, afforestation, farm forestry, pasture development are in progress in the above districts. The Table 1 presented depicts the waterhed management plan under progress.

9.8.3 Features of groundwater in arid regions of Gujarat

9.8.3.1 Kutch region is mainly occupied by Deccan trap rocks. These rocks are either exposed or covered with their alluvial cover. These rocks yield moderate quantities of ground water through open wells. The permeability of lava flow is low and varies widely. The younger basalt gives better yields in wells while the older basalts are generally compact and devoid of major joints. The zone of weathering between two successive flows, forms ground water bearing horizon.

9.8.3.2 The alluvial deposit extends upto Banaskantha. The deposits consist of well sorted fine to coarse grained material. This formation yields large quantities of groundwater in wells and tubewells. Major groundwater exploitation is confined to this formation only. The contact between the eastern hilly areas and alluvium is well demarcated (recharge area table 2). Here the thickness of alluvium ranges between 30 to 50 meter. The thickness of alluvium deposits increases towards so thwest i.e. towards the discharge area and groundwater occurs under semi-confined and confined condition. The thickness of alluvium deposits vary between 5 to 35 m below ground level which can be developed

generally within 300 metre depth since below 300 metres depth, the available quality of groundwater is not suitable for irrigation.

9.8.3.3 From the study it is observed that the quality of ground water from the recharge areas down to the central alluvial zones is within suitable limits for irrigation but the quality zones is within suitable limits for irrigation but the quality of groundwater starts deteriorating westwards i.e. towards discharge area. In such areas the lower aquifers yield better quality of ground-water and in such areas tubewells are envisaged by tapping deep confined aquifer and providing cement sealing to avoid mixing of groundwater from saline unconfined aquifers with fresh water from confined aquifers.

9.8.3.4 In view of the hydrogeological data, availability of surplus groundwater potential, there is a feasibility of development of ground water (construction of additional tubewells in alluvial tracts). The dydrological characterisatics of ground water in the proposed area of development is presented in Tables 2.3.4 and 5.

Table 1 : Watershed management plan in the arid and semi-arid region of Gujarat.

	District	Arid zone %	Semi-arid	No. of Taluka	DFAP Taluka	No. of sub-watersheds	Area of watersheds (ha)	Details of river and sub-river system	Area* proposed to be treated soil & water coms (ha)	Rain-gange in DFAP Taluka	Wind** oro-sion pilot pro-ject under progress	Average annual rain-fall (mm)
1.	Kutch	100	-	9	7	3	5056	Kankavati	1340	47 (7 taluks)	Yes	340.40
2.	Banaskantha	18	82	11	6	31	119702	Banas, Sara-swati, Umerda-shi Arjuni Rel, Voh, Khari etc.	5649	54 (7 taluks)	Yes	750.70
3.	Mehsana	7	93	11	2	8	22450	Sabarmati, Rupen Puspe-wati, Rupar Khari etc.	6410	19 (2 taluks)	Yes	613.00
4.	Rajkot	6	94	12	2	115	259095	Aji, Moj, Machhu Denu etc.	7853	16 (2 talkus)	-	594.30

* Soil & water conservation programme on watershed basis - Contour bunding, terracing, gully, plugging, land levelling, Kyri making, water harvesting, structure like farm pond, farm forestry and pasture development.

** Shelter bolts - Siras, Sisoc, Acacia tortills, Amea, Ncom.

Table 2 : Recharge and draft including projects : programme upto 1981-82 (3 DPAP districts) in Gujarat.

Sl. No.	District	Recoverable recharge from all sources in mcm/year (1978-79)	Recoverable recharge from all sources in mcm/year (1981-82)	Not draft in mcm per year (1978-79)	Est. fractional recoverable recharge presented by not draft in % (78-79)	Not draft in mcm/year (81-82)	Est. fractional recoverable charge represented by not draft in % (81-82)	Existing re-tube-wells	Proposed wells 1982
1.	Banaskantha	888.96	888.96	249.09	28.00	388.38	43.67	365	150
2.	Kutch	383.97	383.97	177.96	46.34	201.40	52.45	80	15

Table 3 : Groundwater potential available in proposed area of development in Banaskantha, and Kutch districts

Sl. No.	Name of district	Inflow in mcm/ year	Govt. T.W.	GWRDC T.W.	Private T.W.	Draft in mcm/ year	Not available in mcm/ year	70% not available in mcm/year	Proposed tubewells programme	Draft of proposed programme in mcm/yr.
1.	Banaskantha	420.00	106	214	332	102.50	317.50	222.25	700	182.00
2.	Kutch	139.62	68	64	91	33.82	105.80	74.06	150	42.00

Table 4 : Quality of groundwater in the proposed area of development in Banaskantha, Mehsana and Kutch districts

Sl. No.	District	No. of tubewells with discharge				Range in total dissolved salts in ppm		Remarks
		1500-22000 GPH	22000-34000 GPH	Above 34000 GPH	Total	From	To	
1	2	3	4	5	6	7	8	9
1.	Banaskantha	140	210	350	70	500	1700	
2.	Katch	45	90	15	150	500	2500	

Table 5 : Hydrological characteristics of groundwater in the proposed area of development.

Sl. No.	District	Recharge area (km^2)	Artesian belt (km^2)	Ground-water level (range) (m)	Depth of aquifers (m)	Modes of development	Salinity level and extent
1	2	3	4	5	6	7	8
1.	Katch	-	-	5-20	100	Saline area, Tubewell in small part	All levels except small area (10%)
2.	Banaskantha	364	2368	5-20	100	Tubewell	Usable ground-water (40%) and salinity 100-150 m

CHAPTER X

10.0 AGROCLIMATIC APPROACH FOR CROP DEVELOPMENT

10.1 SCOPE

10.1.1 Climate is one of the main controlling factors in the selection of crop species contributing to production in any region and more so in arid and semi-arid regions. Systematic approach is required for crop development and it can be achieved through generation of knowledge on :

i) delineation of agroclimatic zones.

ii) risk analysis in crop production under rainfed conditions for crops of different durations.

iii) systems analysis for identification of crops suitable for early, normal and late sown conditions.

iv) water use pattern by crops in different agroclimatic regions to identify crops with better water use efficiency.

v) frequencies of occurrence of agricultural droughts during different phenophases of crop growth and the influence of magnitude of drought on the productivity.

vi) potential for water harvesting and recycling for stabilising crop production.

vii) climatic conditions conducive for incidence and spread of pests and diseases.

viii) mechanism of evaporation and possible methods of reducing evapotranspiration losses for efficient moisture conservation, and

ix) microclimatological features associated with different cropping systems like monocropping silvi-pasture, agro-forestry, mixed cropping, inter-cropping etc.

10.1.2 The above knowledge will enable us to tailor the cropping systems that match the climatic conditions.

10.1.3 In view of the severe problem of wind erosion, investigations on mechanism of wind erosion and its control, the movement of dust, influence of shelter belts on wind speed reduction and dust movement will be extremely useful in planning measures of soil conservation.

10.2 RESEARCH WORK DONE

Systematic studies have been undertaken at CAZRI since 1962 on different aspects of arid zone climatology and the important contributions made are briefly summarised below :

10.2.1 Delineation of arid and semi-arid regions of India

The arid and semi-arid regions of India upto tehsil level have been demarcated. The percentage area under each climatic zone in different States have been estimated.

10.2.2 Agroclimatic features

(a) Different soil climatic zones based on thermal regime, moisture regime and soil types have been identified not only in respect of the Indian arid zone but also for whole of the country. The duration of normal growing season, dates of its commencement and cessation and the periods of slight, moderate and severe moisture stress during growing season have also been worked out.

(b) Comprehensive agroclimatological survey reports of Bikaner, Nagaur and Jodhpur districts with detailed information on the rainfall distribution, frequencies of occurrence of dry spells and wet spells, water availability periods for crop production etc. have been prepared.

10.2.3 Water balance, evaporation and soil moisture

(a) A model for prediction of evapotranspiration losses under native vegetation have been developed.

(b) Wind regime during the kharif season exerts more influence on evapotranspiration losses compared to the thermal regime.

10.2.4 Microclimatic features of grasses and cropped lands

(a) For successful establishment of grasses in silvipastoral systems, canopy manipulation through lopping for increasing energy penetration is essential.

(b) Lasiurus sindicus grass has got high water and energy use efficiencies compared to Cenchrus ciliaris and Cenchrus setigerus grasses under extreme arid conditions.

(c) Paired and triple row systems of planting pearlmillet helps in decreasing evapotranspiration demand and increasing moisture use efficiency compared to conventional systems of planting in uniform rows.

10.2.5 Rainfall pattern, distribution and rain water use efficiency

(a) Quantification of rainfall, water use patter by livestock, human population, forests, grasslands and cropped lands and rain water use efficiencies in different districts of Rajasthan have been worked out.

(b) Deficit and surplus patterns of rainfall expected once in 5 years and once in 10 years have been identified.

(c) Rainfall patterns in western Rajasthan under early, normal and late commencement of monsoon rains have been analysed.

10.2.6 Risk analysis, systems analysis, droughts, agricultural droughts

(a) The conditional probabilities of occurrence of extremely arid, arid and semi-arid type of conditions following the climatic conditions prevailed during the preceding year, have been studied.

(b) Pearlmillet crop is less vulnerable to drought when the first sowing rains are received from 25th June to 15th July in Jodhpur region.

(c) Moong though a short duration crop is more susceptible to drought compared to pearlmillet.

(d) Satisfactory yield of perlmillet crops is possible in 3 out of 10 years as the crop experiences moisture stress during flowering and reproductive stages of growth under Jodhpur conditions. Satisfactory yield can be obtained in 7 out of 10 years by providing supple-

mentary irrigation to 0.8 ha, by harvesting and recycling of rain water received in a catchment area of 0.2 ha in Jodhpur region.

(e) There is a tendency for the droughts to originate first in the northeastern region around Churu, spread in south-westerly direction into Barmer region and dissipate with an easterly movement into Pali region.

(f) Information on the frequencies of occurrence of mild, moderate, severe and disastrous droughts in different districts has been collected.

(g) Risk analysis in crop production in respect of short and medium duration crops under rainfed conditions in different taluks of Nagaur district on the basis of weekly rainfall data for the years 1901 to 1970 has been attempted.

10.2.7 Shelter belts and micro shelter belts, wind erosion

(a) Wind regime in relation to depletion of soil fertility as influenced by tree shelter belts has been studied at Jodhpur.

(b) Cassia siamea tree shelter belt has got higher effectiveness index in reducing wind speeds compared to Prosopis juliflora and Acacia tortolis tree shelter belt.

(c) Removal of grass cover results in severe wind erosion at a faster rate from the top layers of the soil in the extremely arid regions. Particle size distribution of the dust contains high percentage of silt indicating loss of soil fertility.

(d) Drought during preceding year has a multiplier affect on dust storm activity and desertification process during the succeeding year.

10.2.8 Pests and diseases

(a) High relative humidity coupled with cloudy conditions and low night temperatures during flowering stage of perlmillet are conducive for the incidence of ergot dosease.

(b) A relative warm period after severe wet spell with high relative humidity and increased hours of sunshine are conducive for the incidence of C. cognota pest on moong.

10.3.0 NEED FOR FURTHER RESEARCH

10.3.1 Basic climatological studies :

Since the India Meteorological Department is having the basic infrastructure with adequate climatological data, computer facilities and necessary expertise, the following areas of study are indicated for research in India Meteorological Department.

(i) General Climatology and Agricultural Land Use Planning :

Investigations on agricultural land use planning on the basis of climatological features have to be intensified. During the course of deliberations of the Committee, it was brought out that India Meteorological Department is launching a scheme in this direction in collaboration with University of Udaipur. Involvement of CAZRI in this programme will be meaningful.

(ii) Rainfall Analysis :

Detailed analysis of the spatial and temporal variations of rainfall in arid zone areas. Characteristics of short period rainfall - probability at different levels of occurrence of rainfall of different magnitudes for different durations - Examination of the adequacy of the raingauge network for different investigations and suggestions for its improvement - Information of maximum rainfall recorded as stationwise for different durations from one hour upto 5 days - Districtwise analysis of areal/point rainfall of detect trends, periodicities etc. - Statistics of interspell durations for different months of the year - Statistical characteristics of the dates of commencement of monsoon rains for different districts -Analysis of year to year variation of rainfall with special reference to occurrence of drought years.

(iii) Estimation of evapotranspiration in arid areas :

Special variation of evaporation/evapotranspiration and optimum network required for adequate observation of the same - soil climate warning of the arid area based on moisture availability for different

months - Indices for estimating aridity and moisture stress on crops - Planning of soil moisture network and its establishment with the help of State authorities.

(iv) Pests and Diseases :

Meteorological aspects of pests and diseases including factors governing locust breeding and locust migration.

(v) Flood Meteorology :

Synoptic study of floods in arid areas and their consequences - Water resources potential of heavy rainfall spells leading to floods.

(vi) Water Balance Studies :

Water balance study including atomospheric moisture budget in limited areas with the cooperation of State and Central Group Water Board.

(vii) Development of agro-climatic zonewise models for forecasting crop yields for selected crops in selected regions of the area.

10.3.2 Future lines of agroclimatological research :

The CAZRI has got necessary facilities, scientific talent and infrastructure, agroclimatological investigations on the following aspects indicated below should be taken up by CAZRI, Jodhpur.

(i) Detailed delineation of cropping zones upto tehsil level on the basis of moisture availability index, Predominant soil type and prevailing cropping systems.

(ii) Drought vulnerability of crops during different phenophases of crop growth depending on the period of sowing of crops.

(iii) Crop weather models for major rainfed crops grown in different agroclimatic regions.

(iv) Productivity potentials of rainfed crops.

(v) Water use pattern of major rainfed crops using lysimeters.

(vi) Microclimatic features congenial for optimization of silvi-pasture, agro-forestry, mixed and inter-cropping systems.

(vii) Development of appropriate code for classification of agricultural droughts.

(viii) Energy flow in desert ecosystem incorporating vegetation and livestock.

(ix) Influence of climate on intensity of cropping in arid and semi-arid regions.

(x) Wind erosion and its control.

10.3.3 Present evapotranspiration observational network in the arid regions :

The India Meteorological Department has installed gravimetric lysimeters at the following three stations in Indian arid zone.

	Station	Location
i)	Jodhpur	Central Arid Zone Research Institute Campus, Jodhpur.
ii)	Rajkot	GAU Research Farm, Rajkot.
iii)	Hissar	HAU Campus, Hissar.

10.3.4 Need for future observational network :

The present network of lysimeters is considered as inadequate in view of the diversity in the cropping systems followed in different parts of the arid zone. The India Meteorological Department expressed its inability to expand its network. Therefore, it is suggested that the network of lysimeters has to be improved to collect information on water use pattern by rainfed crops in different climatic zones identified by the Committee as shown in Fig. 1. However, it is recommended that the India Meteorological Department should provide the necessary technical assistance for installation and maintenance of the lysimeters.

10.3.5 Lysimeters for crop water use measurement :

CAZRI should identify different agroclimatic zones taking soil types also into consideration and establish lysimetric stations for con-

tinuous observations of evaportranspiration from crops and grasslands. It is also suggested that CAZRI should take up the responsibility of scrutiny, analysis and interpretation of the data.

10.3.6 Soil moisture observation :

There are number of substations/R.M. & S.C. of CAZRI in zones 1 to 4. Therefore, there is need to establish soil moisture observation network in zones 5, 6 and 7 along with lysimeter observatories.

10.4 OUTLINE OF AN APPROACH FOR DELINEATION OF CROPPING ZONES IN NORTHWEST ARID ZONE BASED ON MOISTURE AVAILABILITY INDEX

10.4.1 Background :

The National Commission on Agriculture have carried out an analysis on cropping patterns in relation to rainfall for whole of the country. This has indeed been a very illuminating exercise. This study had used the tehsilwise normal monthly rainfall distribution as the parameters. There is a scope for further improvement considering the weekly distribution of the moisture availability index (MAI) during different phenophases of crop growth to identify most suitable crops for the given region.

10.4.2 Plan of Work :

The ratio of actual evapotranspiration to the potential evapotranspiration (AE/PE) indicates the rate at which water is available compared to the demand and it is called moisture availability index (MAI). The weekly MAI values can be computed using climatic water balance model.

10.4.2.1 The MAI is classified into five types as shown below :

Value of MAI	Classification	
0.00-0.24	Dry	-
0.25-0.49	Sub-moist	A
0.50-0.74	Moist	B
0.75-0.99	Sub-humid	C
1.00 or more	Humid	D

10.4.2.2 The MAI values have been computed districtwise and the different climate cropping zones in Rajasthan have been identified on the basis of:

i) total growing season

ii) periods of assured moisture availability for crops of different duration under normal conditions as shown in Table 1.

10.4.3 Further work

This is only a preliminary projection. Detailed delineation has to be carried out by CAZRI considering the data available for as many stations as possible through incorporation of :

i) weekly values of MAI for all tehsil stations;

ii) predominant soil types;

iii) prevailing cropping systems.

Table 1 : Different climatic zones and their possible cropping systems

Climate cropping zone	Duration of growing season	Moisture availability conditions	Possible cropping systems
1	Less than 11 weeks	-	Grasslands
2	11 weeks	(B+C) for 7 weeks from 3rd week	Short duration pulses
3	12 to 14 weeks	(B+C) for 8 weeks from 5th week	Pearl millet, short duration pulses and short duration oil seeds
4	15 to 20 weeks	B+C for 10 weeks from 5 week	Jowar, Groundnut
5	15 to 20 weeks	C+D for 10 weeks from 5th week	Maize
6	21 to 29 weeks	C+D for more than 12 weeks from 5th week	Cotton; chillies and intercropping systems
7	Greater than 30 weeks	C+D for more than 14 weeks from 5th week	Double cropping systems

CHAPTER XI

11.0 ALTERNATE SOURCES OF ENERGY IN ARID ZONE

Arid zone in India, which largely covers western Rajasthan and some parts of Gujarat, Andhra Pradesh and Haryana, is having scanty and erratic rainfall which results in sparse vegetation causing heavy shortage of firewood, a cooking fuel of rural poor. Water in this area is saline and as such is unfit for drinking and other domestic use. Most of the villages in the arid region are not yet electrified. Therefore, there is considerable scope for exploitation of alternate sources of energy to meet the energy requirements for domestic and agricultural applications like cooking, desalination, lifting of water for irrigation, dehydration and preservation of agricultural products, water heating etc.

11.1 SOLAR ENERGY POTENTIAL

11.1.1 Arid zone of India is blessed with enormous amount of solar energy as it receives maximum solar radiation in India and is second highest in the world next to Sahara Desert. Mean daily total solar radiation falling on horizontal surface of some important stations is given below.

Month	Mean daily total radiation in $Kwhm^2$					
	Jodhpur	Bhavnagar	Ahmedabad	Bhopal	Madras	Hyderabad
Jan.	4.6	5.0	4.7	5.6	5.1	4.8
Feb.	5.4	5.8	5.7	6.3	6.3	5.9
Mar.	6.4	6.9	6.5	6.8	6.8	6.1
Apr.	7.2	7.1	7.2	6.9	6.7	6.2
May	7.4	7.6	7.2	6.9	6.5	6.7
June	7.0	6.4	6.5	4.8	5.8	5.4
July	6.8	4.5	4.8	3.8	5.2	3.9
Aug.	5.6	4.3	4.7	5.0	5.5	4.1
Sept.	6.0	5.9	5.6	5.4	5.6	3.9
Oct.	5.8	6.0	5.8	5.7	5.0	4.6
Nov.	4.9	5.2	4.9	5.4	4.2	4.1
Dec.	4.5	4.6	4.9	5.2	4.4	4.6
Annual	6.0	5.8	5.7	5.7	5.6	5.0

Source : Garg, H.P. (1977) Solar Energy Research at CAZRI. URJA February issue PP 24-29.

11.1.2 Cloudy conditions prevail during months of July and August in arid region but the total radiations received during these months are higher as compared to other regions. During winter season, though total

radiation received is less, yet the amount of direct radiation is more as clear skies prevail. On an average, the sunshine is available at Jodhpur for more than 3,500 hours in an year.

11.2 SOLAR ENERGY UTILIZATION

Very rightly, CAZRI started research on solar energy utilization from the year 1971 and made significant contribution in developing techniques of harnessing solar energy. Some of the achievements made by CAZRI and several other institutions have been briefly summarised below :

11.2.1 Solar Water Heaters

Several research laboratories in India have contributed to the development of solar water heater over the last 25 years. Prominent among them are N.P.L., New Delhi, C.B.R.I., Roorkee, C.A.Z.R.I., Jodhpur and PAU, Ludhiana. All the solar water heaters developed in India utilise flat-plate principle. A brief account of few solar water heaters developed at C.A.Z.R.I. and tested under arid environment is given below : -

(a) Built in storage type solar water heater :

The solar water heater is of 100 litres capacity and provides hot water at 55-60° C in the afternoons and at about 40°C in the early mornings of winter season. The cost of the solar water heater is about Rs.600/- and its life period is expected to be 8 years and 12 years when used during the whole year and winter season respectively.

(b) Natural circulation type solar water heater :

This solar water heater can provide hot water at a temperature of 60°C during the afternoons and at 50°C during the early mornings of winter season. The water temperature goes upto 80°C during the afternoons of summer months. The solar water heater of 100 litres capacity will cost about Rs.1400/-.

(c) Cylindrical type solar water heater :

The cylindrical type of solar water heater provides 50 litres of hot water at a temperature of 55-60°C during the afternoons of winter

months and its cost is Rs.150/-. If the hot water is required for use in the next day morning, it has to be transferred to a storage drum which can be made at an additional cost of Rs.150/-.

Investigations were also carried out on

i) Selection of suitable black coatings for collector surfaces.

ii) Optimisation of air gap in flat plate collectors.

iii) The effect of number cover glazings of glass and PVC on the performance of water heaters and

iv) The effect of insulation in minimising heat losses.

11.2.2 Solar agricultural dryers

11.2.2.1 Solar dryers are broadly of two types, viz., cabinet type and forced convection type. In India small cabinet dryers for drying fruits and vegetables have been developed at C.A.Z.R.I. Jodhpur, IIT, Kanpur, Annamalai University, Tamil Nadu. Forced convection type dryers have been developed at CAZRI, Jodhpur, IARI, New Delhi, IIT, Kharagpur, and Annamalai University, Tamil Nadu. Following type of solar dryers for dehydrating fruits, vegetables, chillies etc. have been developed at CAZRI, Jodhpur :

a) Simple solar cabinet dryer

b) Solar cabinet dryer with automatic temperature regulation mechanism

c) Solar dryer with maximum energy capture

d) Forced convection type solar agricultural dryer.

11.2.2.2 The simple cabinet dryer can be used for dehydrating 15-20 kg fruits, vegetables and chillies in about 4 to 6 days. Sometimes, the temperature inside the simple solar cabinet dryer increases beyond 70°C resulting in loss of flavour and charring of the dried product. Therefore, it has been improved by providing a well designed chimney to enhance circulation of air whenever the temperature increases beyond 60°C. After improvement, it is found that (i) the drying is faster in improved dryer by about 20 per cent and (ii) the colour and flavour of the dried product will not be affected.

11.2.2.3 The further improve the drying rate, a solar dryer for maximum energy capture has been designed. In this dryer, 15 to 20 kg of drying material is kept in inclined trays and drying time can be reduced by nearly 40 per cent compared to simple solar cabinet dryer.

11.2.2.4 The forced convection type agricultural dryer consists of a number of air heaters connected in series with a drying bin. Hot air is circulated through the air heaters to the drying bin with the help of an electric blower. The dryer can be used for dehydrating about 1 quintal of chillies in one day. As the drying material is not exposed to sunlight its colour will not be affected much.

11.2.3 Solar Stills

11.2.3.1 The problem of getting potable water in arid, semi-arid and some coastal areas is acute. The salinity of ground water in arid areas of western Rajasthan vary from 5000 ppm to 10000 while sea water has an average salt content of 35,000 ppm. The water with salinity content of 500 ppm is generally considered fit for drinking purposes and 1000 ppm for agricultural purposes. Solar stills can play vital role in converting saline water into potable water. In India the earliest experiments in solar distillation were conducted in N.P.L., New Delhi. Defence Laboratory Jodhpur has developed a small portable solar desalination kit meant for jawans. C.S.M.C.R.I., Bhavnagar is doing extensive work on laboratory and large scale solar desalination. It has developed a large scale solar distillation plant having a capacity of 1090 litres of distilled water per day. Work on solar distillation was started at C.A.Z.R.I., Jodhpur in the year 1973 and since then many systematic studies have been carried out to study the distilled water output as influenced by (a) climatic, (b) operational and (c) design parameters of single and double sloped solar stills under arid conditions.

11.2.3.2 The design of double sloped solar still has been optimized to get distilled water of 3 to 6 litres/sq.m/day depending upon the season. The solar stills cost about Rs.200/- per sq.m. area. Recently a step basin type solar still has been developed. The distilled water output can be increased by 20 per cent using this solar still.

11.2.4 Solar cookers

11.2.4.1 In rural India, nearly 50% of the cooking fuel is met from firewood which is in short supply in arid regions and as such there is need to pay more emphasis on the utilization of solar energy for cooking in this region.

11.2.4.2 CAZRI, Jodhpur studied in detail the relative performance of N.P.L. Cooker, Hot box type cooker, step reflector type cooker, solar steam cooker and solar oven and it was found that solar oven is more useful for cooking of rice, dal and vegetables, boiling of milk and tea. Therefore, the solar oven has been further improved by (i) optimising the cooking chamber and (ii) providing a rubber gasket round the circumference of the openable door to minimise heat losses. The improved solar oven costing about Rs.600/- can be used from morning 8.00 AM to evening 5.00 PM on clear sunny days and it can save a maximum of 50 per cent fuel consumption for about 7 to 8 months in an year for a small family.

11.2.5 Dual and Multipurpose solar energy devices

The solar devices are seasonal in use; e.g., water heaters are more useful during winter, dryers during harvesting season and so on. Therefore, CAZRI, Jodhpur has developed following devices which can be used for more than one purpose :

(a) Solar water heater-cum-steam cooker :

It provides 100 litres of hot water at a temperature of 60°C during the afternoons and 50°C during the early mornings of winter season. The steam cooker provided with the unit can be used for cooking rice, vegetables and dal during summer season. The unit can be fabricated at a cost of Rs.1600/-.

(b) Solar water heater-cum-solar still :

It provides 100 litres of hot water at a **temperature 50-55°C** in the afternoons even during the winter season in addition to about 3 to 6 litres of distilled water per day. If hot water is required for use in the next day morning it has to be transferred to an insulated drum. The cost of the device is about Rs.600/-.

(c) Multipurpose solar energy device :

The unit can be used as a solar water heater cum still throughout the year as explained above. The unit can also be used as an improved solar cabinet dryer for dehydrating 15-20 kg of fruits, vegetables chillies etc. in about 4-6 days during harvesting season as and when required with simple adjustments. The cost of the unit is about Rs.650/-.

11.2.6 Solar Pump :

In the arid areas farmer depends on rain which is scanty and erratic and if it is brought under irrigation, crop production can be substantially increased. From the operational point of view, self contained energy units e.g. solar pumps are likely to prove more efficient and provide more years of trouble free service.

(a) Thermal solar pumps :

CSMRI, Bhavnagar has developed a solar pump operating on the energy received from flat plate collectors. Work is also in progress at CAZRI, Jodhpur to develop a solar pump.

(b) Photovoltaic pumps :

This pump operates on a solar cell panel which converts solar radiation directly into electricity. These pumps are most suitable for arid and other remote areas for following reasons :

i) No moving part, hence maintenance is easy;

ii) Conversion efficiency is higher.

Photovoltaic pumps have been developed at CEERI, Pilani and CEL, Sahibabad. These pumps use solar cells with nearly 10% conversion efficiency. These pumps have been tested and found useful for small and marginal farmers.

11.2.7 Solar thermal storage system :

Because of the intermittent nature of solar energy, work on development of suitable heat storage systems using phase change materials is in progress. A thermal storage system using paraffin wax as